PLANT PATHOLOGY

A RECORD OF CURRENT WORK ON PLANT DISEASES AND PESTS

Published quarterly for the
Ministry of Agriculture, Fisheries and Food
Plant Pathology Laboratory
Harpenden, Herts

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FRIT FLY IN SPRING OATS

I. SAMPLING FOR FIRST GENERATION SHOOT ATTACK

Contribution from the Conference of Advisory Entomologists, National Agricultural Advisory Service, summarized by A. H. Strickland, of the Plant Pathology Laboratory, Harpenden, Herts

In 1946, the Conference of Advisory Entomologists decided to make an annual survey of frit fly (*Oscinella frit* L.) incidence in oat crops in England and Wales. Work was started on infestations in spring oats at tillering, in spring and winter varieties at harvest, and later on infestations in ryegrass (*Lolium perenne* L., and *L. multiflorum* Lam.) leys (Thomas, 1954). In 1953, the Conference agreed that the results obtained up to that time were not easy to interpret, and experimental plot work was put in hand to establish the relationship between frit attack and oat yield with greater precision than could be expected from extensive survey work. A summary of the plot work has already been published (Strickland, 1958), and the present paper is the first of a short series in which the results are presented in greater detail.

Conventionally (Cunliffe, 1924) first generation attack has been estimated by counting the total and fritted (deadhearted) tillers in unit lengths of crop row. There are disadvantages in this method: first, timing must be accurate with respect to the growth stage of the crop and the emergence of adult flies from their winter hosts; Cunliffe, in fact, emphasizes that counts should be done 12–15 days after the newly hatched larvae have entered the shoots. He points out that earlier estimates may lead to errors as great as 30 per cent in estimating the extent of the attack. Secondly, physiologically chlorotic tillers can be confused with chlorosis due to frit; and thirdly, deadheart counts give no indication of the numbers of larvae which have died within the shoots before fatally injuring the plant tissues, this being of particular importance where accurate ecological and chemical work are concerned.

Deadheart assessment has, however, the great advantage of simplicity and ease of application in the field; the same cannot be said for the alternative of shoot dissection under a binocular microscope in the laboratory. Both methods have been used in the Advisory Entomologists' work, and are discussed in this paper.

DEADHEART ASSESSMENT

Because of its simplicity, this method has been used most extensively in the work under review. There is a degree of uniformity in individual assessments at any one time and place, as is illustrated by some results obtained in Hertfordshire in 1958. These are typical of the great majority of the tiller count data obtained since 1953, in the recording of which fifty-two observers took part at one time or another.

Two observers took part in the Hertfordshire test. Each of them assessed attack in 10 feet of drill in half of eight pairs of plots in a date-of-drilling trial at weekly intervals from May 20 until June 4, and on four pairs on June 11. Frit attack ranged from zero (on four plots at the first visit) to 20 per cent (on three plots at the last visit). The individual counts were transformed to angles before analysis, the complete series by the first observer giving a mean of 10·0, and by the second of 11·3. The difference of $1 \cdot 3 \pm 0 \cdot 61$ suggested that small observer

differences might exist, but they are clearly too small to influence the results to any marked extent. It is reasonable, therefore, to present the mass of the co-operative results on the assumption that major differences in intensity and distribution of attack are almost certainly real differences, for which biological explanations must be found.

In the field work, plot size was initially standardized at 1/150th acre, and treatments (usually four, but sometimes increased to six or seven) were replicated four times at each site in a randomized block layout. At each visit five sampling stations, each of a 1-foot run of two adjacent rows of drill, were visually examined, and total and fritted shoots recorded. The results from each sample station were expressed as the percentage of damaged shoots, and transformed to angles before analysis.

At the start of the work it was appreciated that sampling schemes of this sort were to some extent arbitrary: greater accuracy of estimation might be expected at high, rather than at low, density levels. Yet for trials extending over the whole country it was necessary to agree on a uniform sampling intensity which would give estimates of known accuracy within the density levels likely to be met. At the end of 1953 a preliminary sampling analysis was done on the shoot-counts from six visits to four sites in Yorkshire, Nottingham, Essex, and Monmouth at which attack varied from none to over 50 per cent. The overall angular mean was 25·5 (= 18·5 per cent) with a variance, based on four replicates of five samples per plot, estimated at 8·86. With a coefficient of variation of just under 12 per cent the method seemed capable of detecting, as statistically significant at the 5 per cent point, density differences of the order of 33 per cent.

Subsequently a more detailed analysis was done. This was based on results from Durham, Yorkshire, Staffordshire, Nottingham, Essex, Gloucester, Berkshire, Kent, Devon, Monmouth, Brecon, and Radnor, for the years 1953, 1954, and 1955. The overall angular mean infestation was 21·1 (= 13 per cent) with a variance of 3·77. The pooled analysis took the form:

Factor	*Degrees of Freedom*	*Mean Square*
Between plots ..	243	75·49
Within plots ..	3,304	30·57

These data have been used to calculate the standard errors which might be expected when sampling visually for shoot attack at different sample and replication levels.

TABLE 1

Standard Errors Expected when Sampling for Shoot Attack by Visual Inspection

Replicates per Trial	Feet of Row Inspected in each Plot					
	2	*4*	*10*	*20*	*40*	*200*
1	6·3	4·9	3·9	3·5	3·2	3·1
2	4·5	3·5	2·8	2·5	2·3	2·2
4	3·1	2·5	1·9	1·7	1·6	1·5
6	2·6	2·0	1·6	1·4	1·3	1·2
8	2·2	1·7	1·4	1·2	1·2	1·1
10	2·0	1·6	1·2	1·1	1·0	1·0
100	0·6	0·5	0·4	0·4	0·3	0·3

As is often the case with insect assessment, increasing the sampling rate within a plot does not give results proportional to the extra effort involved. Replication over plots gives a better return: from Table 1 it can be seen that a single 2-foot sample, taken on each of ten plots, would give an estimate with a sampling error the same as that from looking at twice the number of samples, taken at the rate of five from each of four plots.

These results also indicate the limitations of this sort of experiment. It might occasionally be necessary to establish the reality of differences of 10 per cent between treatment means. This could only be done with a randomized block layout if treatments were replicated eighteen times, and about 200 feet of row were looked at on each plot. If replication costs less than visual inspection, the same accuracy could be obtained by looking at 2 feet of row on each of a hundred replicates. It is in cases like this that the entomologist has to weigh up very carefully the question of plot size in relation to the biology of the pest and its host plant. A hundred replicates of 1-sq. yard plots might be economically practicable, but biologically unsound.

DIFFERING LEVELS OF ATTACK

During the arithmetic involved in arriving at the data in Table 1 it was noticed that, within quite restricted ranges of attack, the within-plot variances were not consistent from year to year. This is illustrated in Table 2, which is based on results from the same localities as Table 1. In 1953, shoot attack was distributed rather less uniformly within plots than in the two following years.

TABLE 2

Within-Plot Variances for Shoot Attack Estimates for Three Years

Year	Less than 5 per cent of Shoots Attacked		6–25 per cent of Shoots Attacked		More than 25 per cent of Shoots Attacked		Average Yearly Mean Square
	Degrees of Freedom	*Mean Square*	*Degrees of Freedom*	*Mean Square*	*Degrees of Freedom*	*Mean Square*	
1953	160	36	116	40	172	52	43
1954	212	30	120	25	84	20	25
1955	1,840	24	512	22	88	26	24
Average Mean Squares		30		29		33	31

Analysis of these variances after logarithmic transformation confirms the unusual variability of the 1953 results at the 5 per cent point, the differences between levels of attack being unimportant. The latter result is not surprising: attacks exceeding 30–40 per cent were rare, and virtually no data are available from which to estimate variances over the upper half of the scale. In this connection, another analysis was done on results from seven sites and two years over three levels of attack; this confirmed that variances do not change appreciably up to infestation levels averaging 36 per cent.

The reasons for abnormal variability in 1953 are obscure; it might have been argued that, as this was the first year of detailed plot work, the field observers were unfamiliar with the visual inspection method and that their assessment errors were greater for this reason. But most of those who did shoot-counts in this year were fully cognisant of the method, and had used it previously in the work reported on by Thomas (1954).

EFFECTS OF LOCALITY, TREATMENT, AND VARIETY

Three other analyses have been done on the visual shoot count variances: to see whether an early spray of DDT affected the normal pattern of infestation, whether there were any major differences in infestation pattern in different parts of the country, and to confirm that infestation patterns were similar in two popular spring oat varieties.

In the first analysis mean squares were calculated for two untreated and two sprayed plots at each of five sites (north and south Wales, East Midlands, South-east, and South-west Regions) for the years 1953 and 1954. The treated plots had been sprayed with 25 per cent DDT emulsion (4/5ths gallon in 100 gallons water per acre) at least two weeks before assessment at each site. Attack was generally low, averaging 6·4 per cent on the untreated, and 5·5 per cent on the treated, plots. However, it was sufficiently high to indicate gross differences in distribution pattern if, for instance, the ovipositing flies had been behaving normally on the untreated plots but aggregating on parts of the sprayed plots on which DDT deposits were minimal. The treatment analysis, in logarithmic notation, is given below:

Factor	*Degrees of Freedom*	*Mean Square*
Treatments	1	0·175
Treatments × Years	1	0·026
Treatments × Sites	4	0·142
Treatments × Years × Sites	4	0·071

Testing the combined variances T + TYS against TS + TY (Snedecor, 1957) gives a ratio of 1·46 compared with 5·79 needed for significance at the 5 per cent point. There is thus no evidence that the ovipositing flies behaved abnormally on the sprayed plots.

In the second analysis the within-plot variances were looked at over the 1953 and 1954 seasons at seven localities: Yorkshire, Nottingham, Berkshire, Essex/Kent, Monmouth, Brecon, and Radnor. With the exception of Essex/Kent, the trials were on the same, or closely neighbouring, farms in the two years, while the Essex and Kent farms, though 70 miles apart, were similar topographically. Attack averaged 15·3 per cent over all sites, and the data were grouped into three levels of damage: 0–3, 4–10, and 11–25 per cent loss of shoot, before analysis. After logarithmic transformation the variances gave the following analysis:

Factor	*Degrees of Freedom*	*Mean Square*
Sites	6	0·075
Sites × Years	6	0·176
Sites × Damage	12	0·152
Sites × Years × Damage	12	0·079

The combined variances S + SYD give an insignificant ratio when tested against SY + SD, and it seems clear that larval infestation patterns did not differ appreciably over two seasons at these widely separated sites.

The third analysis, done on results from the varieties Star and Sun II grown in Northumberland, Nottingham, Kent, Devon, and Brecon, in 1955, gave no indication of varietal differences in infestation pattern up to the level of 15 per cent shoot attack.

DISSECTION ESTIMATES

Visual deadheart assessment on 10 feet of drill involves inspection of about 150 plants (3–500 shoots, according to growth conditions) per plot. Nothing approaching this sampling intensity could be managed with dissection samples in the present work: initially ten shoots, latterly twenty-five plants, per plot were dissected.

This work was started by the Advisory Entomologists at Cardiff (Fidler, 1958) in 1955. In 1956, the workers in Kent did a careful check on the errors involved, two observers taking plant samples independently from the same set of twenty-eight plots and dissecting them in the laboratory. The 140 plants (five from each plot) dissected by the first observer had 820 shoots, and signs of larval damage were found in 484 of them; the second observer dissected 751 shoots, of which 428 were damaged; the percentage infestations were 59 and 57 respectively. After angular transformation the individual results were analysed: the mean difference of $1 \cdot 4 \pm 1 \cdot 94$ showed that observer effects were unimportant; in fact, in only one out of the twenty-eight pairs of counts was there a difference large enough to have been due to factors other than sampling error.

In 1958, dissection samples of twenty-five plants per plot were examined from trials in Northumberland, Yorkshire, Nottingham, Warwick, Bedford, Hertfordshire, Wiltshire, Monmouth, and Denbigh. Infestation varied between 1 (Wiltshire) and 69 (Yorkshire) per cent, the average being 12·5. These results have been expressed in terms of five samples of five random plants each per plot, and pooled for analysis:

Factor	*Degrees of Freedom*	*Mean Square*
Between plots ..	69	104·77
Within plots ..	248	92·57

These mean squares have been used to calculate standard errors (Table 3) which might be expected when sampling for shoot attack by dissecting different numbers of plants from a range of replicate levels. It should be stressed that the results refer to one season only, though as the visual assessment data for 1958 gave variances similar to the averages shown in Table 2 there is no reason to think that 1958 was atypical, or that the results are not generally applicable.

TABLE 3

Standard Errors Expected when Sampling for Shoot Attack by Dissection of Random Samples of Plants

Replicates per Trial	Number of Plants Dissected per Plot					
	5	*10*	*25*	*50*	*100*	*500*
1	9·7	7·1	4·9	3·8	3·2	1·8
2	6·9	5·0	3·4	2·7	2·3	1·3
4	4·9	3·6	2·4	1·9	1·6	0·9
6	4·0	2·9	2·0	1·6	1·3	0·7
8	3·4	2·6	1·7	1·4	1·1	0·4
10	3·1	2·2	1·5	1·2	1·0	0·3
100	1·0	0·7	0·5	0·3	0·3	0·2

The results in Table 3 refer to an angular mean infestation of 21·9, which is virtually the same as the inspection mean of 21·1 to which Table 2 refers. The figures in the two tables can thus be compared directly. They suggest that mean infestations estimated by dissecting twenty-five plants from each of four replicates carry errors slightly higher than those attaching to the visual routine discussed earlier in this paper. At less intensive rates of sampling and replication, visual inspection gives appreciably smaller errors than dissection; and where time and laboratory space are at a premium this should be borne in mind.

At high sampling rates, on the other hand, dissection gives slightly less variable results than the visual method; dissection of 150 plants per plot—the same number as would normally be inspected—should give estimates with standard errors of about 11 per cent for one, and 5 per cent for four, replicates.

Dissection takes time, and when first and second stage larvae have only been active for a short while tissue damage is often hard to see. A week after infestation, damage is usually quite easy to see, and there is little risk of confusing it with physiological wilting where the tissues, though chlorotic, are still intact and show no signs of biting. It is at this stage that dissection is most useful, for two reasons. First, by proceeding on a sufficiently intensive basis it is possible to get remarkably precise estimates of infestation. The rather small errors necessary to detect a 10 per cent difference in treatment means, for example, can be expected if 500 plants are dissected from each of six replicates, or 100 from each of fourteen replicates. Secondly, estimates can be made a week earlier than by inspection. This is important where chemical work is concerned, as worthwhile levels of attack can be shown to exist before systemic or partially systemic chemicals are applied, and applications can be made before many of the shoots have been damaged beyond recovery.

The main disadvantage (apart from its time-consuming nature) of dissection in chemical trials, lies in the possibility of systemic action. Shoots containing young larvae may be recorded as infested when, in practice, the larvae have already absorbed a lethal dose of insecticide, and will die without killing their host shoots (Fidler, 1958).

Under field conditions there is a relationship between dissection estimates made before, and visual estimates made after, deadhearts have appeared. It is not, of course, possible to apply both methods to the same plants, and normal larval mortality within shoots cannot be assessed until a method for establishing their initial presence, without killing the shoots, has been worked out. The impossibility of making paired observations on the same plants introduces rather large errors into attempts to forecast deadheart incidence from dissection data, and this problem will be discussed in a further paper.

SUMMARY

First generation frit attack in the shoots of spring oats can be estimated by rapid visual inspection in the field, or by careful dissection of plant samples in the laboratory. Both methods are discussed in relation to the sampling errors involved, and tables are presented showing the standard errors to be expected over a range of field sample sizes. Visual data from experiments throughout England and Wales over several seasons suggest that larval infestation patterns do not vary appreciably in different parts of the country, but that attacks may have been more uniform within plots in 1954, 1955, and 1958 than in 1953.

I should like to record my thanks to M. J. R. Healy for statistical advice.

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FRIT FLY IN SPRING OATS

II. THE RELATIONSHIP BETWEEN VISUAL AND DISSECTION ESTIMATES OF FIRST GENERATION ATTACK

Contribution from the Conference of Advisory Entomologists, National Agricultural Advisory Service, compiled by W. I. St. G. Light, of the N.A.A.S., Wye, Kent, and A. H. Strickland, of the Plant Pathology Laboratory, Harpenden, Herts

In the previous paper (Strickland, 1959) visual and dissection estimates of first generation frit attack were discussed with reference to their sampling errors. In this contribution the relationship between the two methods is discussed.

Two aspects have been looked at. First, an increasing number of dissection estimates has been made in recent years, yet much of the early work on frit refers to visual assessment. Theoretically the two methods should give comparable results, at least over a period of some days about two weeks after the spring peak of adult activity. In practice, however, there is often a difference, and there are occasions (in analysis over a series of trials in which one or other method, but not both, have been used) when it is necessary to apply a correction factor if results of both types are to be referred to a third set of data.

Secondly, dissection estimates can be made a week or two before deadheart counts and, provided within-shoot larval mortality is low, it should be possible to forecast likely shoot loss before serious damage has been done, and while there is still time to apply systemic larvicidal sprays to commercial crops.

In the co-operative work on these problems dissection samples were taken on field trials concurrently with, and one, two, and three weeks before, visual assessment.

TRIAL SITES AND SAMPLING DATA

The work was done on trial sites in England and Wales over the four seasons 1955–58, and the results refer to eighty-one sampling visits to fifty-one randomized block experiments which were sited thus:

1955 Longbenton, Northumberland; Methley, Yorks; Gleadthorpe, Notts; Clifton Bury, Beds; Bethersden, Kent; Wantage, Berks; Chipping Sodbury, Glos; Powderham, Devon; Chainbridge, Monmouth; and Tredomen Court, Brecon.

1956 Rodbaston, Staffs; Frampton Cotterell, Glos; Chudleigh, Devon; Usk, Monmouth; Cwrt Lleca, Brecon; Rhuddlan, Flints; and Longbenton, Gleadthorpe, and Clifton Bury.

1957 Cockle Park, Northumberland; Escrick, Yorks; Silsoe, Beds; Ashford, Kent; Drayton, Warwicks; Stoke Gifford, Glos; Gloddaeth Isa, Caerns; and at Wantage.

1958 Munsborough, Yorks; Sutton, Beds; St. Albans, Herts; Kennington, Kent; Lackham, Wilts; Bryn Hen, Denbigh; and at Cockle Park, Gleadthorpe, Drayton, and Wantage.

A summary of sampling rates and dates is given in Table 1, and should be studied before considering the results obtained.

In 1955, the first year in which both methods were used co-operatively, ten shoots were taken from each of four chemically untreated plots at each visit to each site for dissection, while inspection of 10 feet of row on each plot provided the visual estimates; in this year 1,200 shoots were dissected and 30,436 inspected.

In 1956, ten plants were dissected from each of eight plots which received no chemical treatment against first generation attack per site visit; the usual 10 feet

of row were examined on each plot, the pooled averages for this year being based on dissection of 5,756, and inspection of 49,516, shoots. In 1957, the same routine was adopted, only four untreated plots per site being sampled; the averages are accordingly based on 1,108 dissected, and 19,217 inspected, shoots. In 1958, the dissection samples were increased to twenty-five plants per plot, four plots per site, giving 4,555 shoots dissected and 21,518 inspected. Over the four seasons approximately ten times as many shoots were inspected as were dissected.

TABLE 1

Sampling Rates and Times, 1955–58

Year	No. Trials	No. Visits	Sampling Rates per Visit		Average Sampling Date	Range of Sample Dates
			Dissected	*Inspected*		
1955	17	30	40 shoots	40 ft row	June 25	May 24–July 19
1956	14	20	80 plants	80 ft row	June 7	May 23–June 26
1957	10	16	40 plants	40 ft row	May 26	May 6–June 20
1958	10	15	100 plants	40 ft row	June 9	May 23–July 3

The samples were taken at various dates, in accordance with the growth of the individual crops: one count was made when tillering was considered to be complete, and a preliminary count was made at most sites two or three weeks earlier to assess initial attack. The average sampling dates given in Table 1 are the means for all samples in each year and, as can be judged from the ranges given, include early counts made at sites near the south coast, and late counts made as far north as Morpeth, Northumberland. It should be noted here that there is something like two weeks' difference in growth conditions between the north and the south of the country, and counts made in Northumberland in the middle of July are roughly comparable with those made in the south towards the end of June.

Assessment dates varied from year to year; mainly due to differences in sowing date and growth conditions. Average sowing dates were: 1955, April 21; 1956, April 19; 1957, April 10; and 1958, April 15. The first year was characterized generally by a cold dry spring, with a drought which did not break until the end of April, leading to poor early growth conditions; 1956 was also dry, rainfall being 75 per cent of average in April, and 41 per cent in May. In 1957, the weather in March, April, and May was close to normal; while in 1958 the March temperature was 4°F lower than average throughout the country, the first two weeks of April being colder than usual with rainfall generally below average, resulting in poor growth conditions.

ESTIMATES MADE BY THE TWO METHODS ON THE SAME DAY

Pooled shoot attack estimates from all sites at which both methods were used concurrently are shown in Table 2. Dissection gave consistently higher results than inspection, the differences between means for each year being significant at the 5 per cent point. The greatest mean differences were found in 1956, when generally heavy shoot attacks developed all over the country, and in 1957 when the counts were done earlier than usual and it might reasonably be expected that a proportion of the larvae were too young to have caused deadhearts. Detailed larval measurements were, in fact, made at Cockle Park on June 28,

and 20 out of 81 specimens were early instars. Counts here gave a dissection estimate of 36, compared with a visual estimate of 25, per cent attack, a difference which can mostly be explained by larval age at sampling. Taking the north/south differences in growth conditions into account, it seems fair to suggest that this situation may well have occurred at other sites earlier in 1957.

TABLE 2

Angular Mean Percentage Shoot Attack Assessed by Two Methods on the Same Day, All Data Pooled

Year	Dissection Estimates		Visual Estimates		Significant Difference Between Estimates ($p = 0{\cdot}05$)
	Mean	±	*Mean*	±	
1955	17·2	2·29	12·9	1·67	3·6
1956	39·7	3·40	31·6	3·00	5·9
1957	18·1	2·58	11·5	1·74	2·9
1958	23·6	3·89	18·6	3·78	1·9

Successive samples by both methods were taken at four trials, two each in 1957 and 1958, at two sites, and the results are shown in Table 3. With the exception of the early counts (May 6 in 1957 and May 20 in 1958) the standard errors per sample visit averaged about 12 per cent, and nine of the twelve differences in Table 3 are significant at the 5 per cent point. The exceptions emphasize the sort of variability encountered in work of this kind; for although dissection usually gives higher estimates than inspection, anyhow early in the season, this is not invariably so. At Gleadthorpe on June 1, 1956, for instance, dissection of eighty plants gave an estimate of 26·7, compared with a visual

TABLE 3

Angular Mean Percentage Shoot Attack for Four Untreated Plots at Two Sites

Trial Sown	Samples Taken	Dissection Estimate (D)	Visual Estimate (V)	Significant Difference ($p = 0{\cdot}05$)	Ratio D/V
A. Kent, 1957					
March 18 ..	May 6	7·0	1·9	6·3	3·7
	13	21·1	8·1	6·0	2·6
	20	—	9·7	—	—
	June 3	18·7	10·4	7·3	1·8
April 8 ..	May 13	19·5	10·6	4·0	1·8
	June 3	44·4	24·4	4·9	1·8
B. Hertfordshire, 1958					
March 12 ..	May 20	4·8	10·1	5·7	0·5
	28	18·4	12·3	4·7	1·5
	June 4	23·9	17·7	2·8	1·4
April 22 ..	May 20	0·0	5·1	4·8	—
	28	6·0	13·4	8·4	0·4
	June 4	24·3	17·7	3·8	1·4
	11	32·1	27·8	3·1	1·2

estimate of 39·4, the difference of 12·7 in favour of inspection having a standard error of 4·5; while in Bedfordshire on May 17, 1957, dissection of forty plants gave an estimate of 10·8 compared with an inspection estimate of 14·5, the difference in this case (3·7 ± 6·0) being non-significant.

At both the Kent and Hertfordshire sites there is a suggestion that, early in the season, the two methods give estimates which differ proportionately more than at the period of peak deadheart abundance, which usually occurs about the middle of June; there is, in fact, a small but consistent decrease in the ratio between the two estimates as the season advances. To investigate this matter further, the available data from all sites pooled are given in Table 4. They have been divided into pre-peak and peak counts, the former referring to samples taken in the south of the country up to about the end of the first week in June, and in the north two weeks later. The latter counts were done mostly in the third week of June in the south, and up to the middle of July in the north.

TABLE 4

Angular Mean Percentage Shoot Attack Assessed by Two Methods on the Same Day

Division of Pooled Data into Pre-peak and Peak Visual Assessments

Time of Visual Count	Year	No. Trials	No. Visits	Dissection Estimates (D)		Visual Estimates (V)		Ratio D/V
				Mean	±	*Mean*	±	
Pre-peak ..	1955	14	14	16·3	3·85	8·0	2·23	2·0
	1956	14	14	36·2	2·40	29·9	3·92	1·2
	1957	10	14	17·6	2·79	10·5	1·77	1·7
	1958	2	5	13·9	3·73	12·5	1·43	1·1
Peak	1955	13	13	20·4	2·92	18·3	2·23	1·1
	1956	6	6	43·4	6·33	35·6	4·11	1·2
	1957	2	2	31·4	5·65	24·8	6·25	1·3
	1958	9	10	26·3	4·36	20·7	4·09	1·3

There is again a suggestion that estimates made by the two methods differ to a greater extent early in the season than at the peak period; and in 1955, when more than a dozen sites were visited both before and at the period of peak deadheart production, the dissection/visual ratio decreased by half between the two visits. In this connection it is worth quoting the results from two southern sites which were sampled exceptionally late in 1955, the counts having been excluded from Tables 2 and 4 for this reason. A visit to Chainbridge on July 7 gave a D/V ratio of 0·7, while visits to two trials at Gleadthorpe on July 12 gave a ratio of 0·9 on one trial, and 0·0 on the other (where the dissection samples were completely free from damage, while the visual counts showed a 3 per cent attack). At these late dates such results are to be expected; the flies, which lay eggs on young tillers, will mostly have disappeared, and early summer generation emergents are unlikely to be attracted to tillers when panicles are available for oviposition (Jepson and Southwood, 1958). Only rather small numbers of larvae might be expected in dissection samples, while confusion between deadhearted and physiologically wilted shoots can account for the anomaly of finding a greater proportion apparently attacked on visual inspection.

The indication that, except for samples taken very early or unusually late in the season, dissection gives results of the same order as, if slightly higher than,

inspection, has prompted us to calculate within-year linear regression coefficients for visual on dissection results. These are shown in Table 5, from which it is plain that there is little to be gained from using different coefficients to transform dissection estimates to visual terms within the period late May to late June; the pre-peak and peak coefficients both differ significantly from zero, but not from each other.

TABLE 5

Pre-peak and Peak Within-Year Linear Regression Coefficients for Visual on Dissection Estimates of Shoot Attack

Year	Pre-peak Assessments			Peak Assessments		
	f	b	±	f	b	±
1955	12	+0·44	0·110	11	+0·29	0·213
1956	12	+0·69	0·266	4	+0·27	0·295
1957	12	+0·52	0·104			
1958	3	+0·24	0·170	8	+0·92	0·070
All Years	41	+0·53	0·097	25	+0·55	0·121
All Years and Times	+ 0·54 ± 0·072 (71 f)					

f = degrees of freedom; the mean values for individual regression equations can be read directly from Table 4.

While it is clear that the average pre-peak and peak coefficients do not differ appreciably, the individual coefficients in Table 5 do show considerable variation from year to year. Covariance analyses on the two sets of data take the form:

Factor	*Pre-peak Results*			*Peak Results*		
	f	Mean Square	Variance Ratio	f	Mean Square	Variance Ratio
Overall Regression	1	3208·0		1	1674·6	
Deviations between Regressions ..	2	1401·9	25·3	2	676·4	15·9
Deviations from Regressions ..	43	55·4		27	42·5	

These analyses suggest real differences in the regression relationships from year to year, and emphasize the need for discretion in transforming dissection estimates to visual terms, or vice versa. It is, in fact, arguable that, in any one year, such transformations can best be done by using a straightforward D/V or V/D ratio, but this presupposes that both types of estimate will have been made at least on some of the trials to be included in pooled analyses. Where suitable ratios cannot be used the overall regression coefficients, from which variation due to differences between years has been eliminated, can be employed for transforming visual counts to dissection terms:

$$V = 5{\cdot}2 + (0{\cdot}54 \pm 0{\cdot}072)\,D$$

or dissection estimates to visual terms:

$$D = 9{\cdot}6 + (0{\cdot}82 \pm 0{\cdot}089)\,V$$

In both equations V = the estimated mean percentage shoot attack assessed visually, and D = the mean percentage assessed by dissection; both percentages are, of course, in angular transformation. Neither equation should be used in conjunction with data which include variate values in excess of 56 per cent attack.

ESTIMATES ON DIFFERENT DAYS

All of the collaborators in the field trials did more than one visual count of attack, and some did more than one dissection as well. It is thus possible to look at the relationship between the two estimates when dissection samples were taken some days before inspection. The results fall conveniently into three groups: dissection one, two, and three weeks prior to inspection, and they are summarized in these terms in Table 6.

TABLE 6

Angular Mean Percentage Shoot Attack Assessed by Two Methods on Different Days

Year	No. Trials	Mean No. of Days Between Counts	Dissection Estimates		Visual Estimates		Ratio D/V
			Mean	±	*Mean*	±	
Group 1. 5–11 days between visual and dissection samples							
1955	4	10	20·8	7·70	11·4	4·68	1·8
1956	4	7	27·9	4·68	33·2	5·02	0·8
1957	4	8	16·6	5·95	16·3	3·99	1·0
1958	2	7	15·3	5·88	20·9	3·81	0·7
Group 2. 12–18 days between samples							
1955	4	15	15·9	6·97	19·2	4·48	0·8
1956	7	16	37·2	3·45	36·0	3·22	1·0
1957	3	14	9·6	1·32	17·1	3·96	0·6
1958	5	13	14·0	3·87	18·3	5·34	0·8
Group 3. More than 18 days between samples							
1955	5	21	11·0	4·48	16·3	3·15	0·7
1956	6	23	34·0	4·98	38·3	3·93	0·9
1957	4	21	21·0	2·35	18·2	4·07	1·2
1958	1	22	22·1	—	36·3	—	0·6

There were appreciable differences between the two kinds of estimate within groups in any given year, but very little difference between the average values over the four-year period in each group. With the exception of the 1955 two-week, and the single 1958 three-week, counts, the dissection samples on which Table 6 is based were taken at the end of May or within the first few days of June, just about at the time of the Cunliffe activity peak (Cunliffe, 1924, Jepson and Southwood, 1958).

Theoretically, dissections made within about the first ten days of June should give better estimates of attack than visual counts, because only a proportion of the total deadhearts will have had time to form. However, within a few days of maturity deadhearts tend to fall away from the ensheathing leaves, leading to under-estimates of the actual numbers of infested tillers in visual samples. In this connection Cunliffe (1924) emphasizes that visual counts should be done 13–15 days after infestation for maximum efficiency. It is therefore unlikely that any relationship between dissection and inspection estimates would be sustained for more than about two weeks. After this time—say, late in June—there is no certainty that the deadhearts counted will have been produced by larvae which were detectable three weeks earlier. Apart from this point, there is the consideration, noted by Fidler and Webley (private communication), that fresh tillers can

be produced after the last of the spring generation of adult flies have disappeared; these late tillers remain undamaged and, at the end of June and in July, can give the impression that attack has decreased.

With these points in mind it is worth looking at the within-year linear regression coefficients in Table 7. First, the values for the individual year coefficients decrease from +2·74, obtained when dissection samples were taken in 1957 before the main fly-activity peak and inspection was done a week later, to −0·62, obtained in the same year when dissection samples were taken at the fly-activity peak and inspection was delayed until after the middle of June.

TABLE 7

Within-Year Linear Regression Coefficients for Visual Counts on Dissection Estimates made One, Two, and Three Weeks Earlier

Year	Five to Eleven Days Between Samples			Twelve to Eighteen Days Between Samples			More than Eighteen Days Between Samples		
	Samples Taken	b	±	*Samples Taken*	b	±	*Samples Taken*	b	±
1955	June 4	+0·58	0·103	June 25	+0·62	0·090	June 4	+0·07	0·403
1956	May 28	+0·87	0·309	June 3	+0·52	0·274	May 31	−0·05	0·394
1957	May 29	+0·50	0·221	May 16	+2·74	1·211	May 26	−0·62	1·140
1958	May 28	+0·61	0·104	May 28	+1·11	0·473	June 10	—	—
All years:		+0·62	0·090		+0·64	0·135		−0·04	0·200
All years, 5–18 days between samples: 0·57 ± 0·083 (40 f)									

Pooling the results for the four years and eliminating variation due to differences between years (which, as in the "same day" analyses discussed above, were significant), three regression coefficients have been calculated and are shown in the penultimate line of Table 7. The first two, referring to one- and two-week intervals between counts, are both positive, practically identical, and differ significantly from zero. The third carries a negative sign, does not differ appreciably from zero, and supports the suggestion that after about two weeks there is no longer a good relationship between results obtained by the two methods.

As there is so little difference between the one- and two-week regressions the data for these time intervals have been pooled in an analysis in which due regard has been taken of year-to-year differences in the quantity of results available. The final overall equations are:

$$V = 10{\cdot}9 + (0{\cdot}57 \pm 0{\cdot}083)\,D, \quad \text{and}$$
$$D = -0{\cdot}4 + (0{\cdot}95 \pm 0{\cdot}139)\,V.$$

V and D are the estimated mean percentages of shoot attack assessed visually and by dissection respectively, both in angular transformation.

The first of these equations can be used to forecast probable visible damage up to two weeks after dissections done about the end of May, while the second can be used to convert mid-June inspection estimates back to dissection terms. Neither should be used with data which include variate values in excess of 56 per cent attack.

SUMMARY

The relationship between estimates of frit fly shoot attack in spring oats assessed by a dissection technique, and by visual inspection, is examined. Appreciable sampling errors are involved with both methods, and, where both have been used at different times on a single experiment, these must be borne in mind before applying a correction factor to the dissection estimates prior to combined analysis in uniform visual terms. When results obtained by one method at a number of sites have to be analysed along with results obtained by the other method at other sites, the application of correction factors may be worth while, and suitable equations are suggested for this purpose. When enough well-based dissection estimates are available it is possible to forecast the likely extent of damage which will actually be visible as deadhearts two weeks later, but it is not possible to forecast for greater periods of time.

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A NOTE ON THE CONTROL OF BROWN ROT OF APPLES BY GRISEOFULVIN

by R. J. W. BYRDE

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No consistent success has followed efforts to control the brown rot disease of apples (caused by *Sclerotinia fructigena* Aderh. & Ruhl.) by means of protectant fungicides applied to the developing crop in late summer. Bennett, Kearns and Marsh (1945) obtained an 80 per cent reduction in a light attack in a Worcestershire orchard by means of ferbam (0·12 per cent active material) or copper oxychloride (0·08 per cent Cu) applied in late June. Both sprays included 1 per cent white oil emulsion; the copper spray caused serious defoliation and fruit russet. Subsequently, however, Moore (1950a) found ferbam, and also ziram, thiram and phenyl-mercury chloride (0·005 per cent) ineffective in trials at East Malling Research Station. In trials at Long Ashton, Byrde (1952a) also found phenyl-mercury chloride ineffective and that dichlone (0·05 per cent), although giving some control, caused fruit injury. Captan, which had proved ineffective against brown rot on plums (Byrde, 1952a), was also found to be of no value against a light attack on apples (Hamer and Hunnam, 1956).

Discussing the failure of protectant sprays for brown rot control, Moore (1950b) stressed the significance of fruit injury as a factor in infection and pointed out that, as a result, they were likely to be effective only when their application happened to coincide with a peak period of fruit injury. Both Moore, and Croxall, Collingwood and Jenkins (1951) have shown the value of measures

against wound agents such as codling moth, earwigs and scab in controlling the disease. Nevertheless, some injuries are unavoidable, and a fungicidal control of the disease would be useful: such a treatment might be particularly valuable for use on plums, where growth splits provide ready access for infection.

During 1956–58, several new fungicides have become available and have been tested against brown rot of apple (in the absence of suitable plum crops). This paper summarizes the results obtained. The fungicides tested were as follows:

n-*Dodecyl-guanidine acetate*, as a wettable powder containing 65 per cent active material. This compound was fungistatic to mycelium of *S. laxa* (Byrde and Waugh, 1958) and has proved effective in the field against apple scab.

Griseofulvin, as a wettable powder containing 50 per cent active material. This compound has a unique action in causing stunting and twisting of hyphae (Brian, 1949). It was effective in laboratory tests against mycelium of *S. laxa*.

o-*Hydroxy-diphenyl*, which was dissolved in toluene, and emulsified with non-ionic emulsifiers.

2, 2¹—Dithiopyridine—1, 1¹—dioxide, as a wettable powder containing 50 per cent active material. This compound, highly toxic to *S. fructicola* (Allison and Barnes, 1956) has been shown to have a chemotherapeutic effect against some plant diseases.

Petroleum white oil (P.31), which was emulsified with non-ionic emulsifiers. This compound was shown by Govindaswamy (1959) to arrest the dissemination of conidia of *S. fructigena*.

The trees used in 1956 and 1958 consisted of a row of some forty dwarf pyramids of the variety Laxton's Superb, to which sprays were applied at high volume by means of a bucket-pump sprayer and hand lance. In 1957 a row of bush trees of Laxton's Superb was used, and sprays were applied at high

Percentage of Fruit Injuries Infected with Brown Rot, 1956–58

Treatment	Concentration of Active Material *per cent*	Percentage of Fruit Injuries made on Dates Stated Subsequently Infected				
1956. Fungicides applied Sept 15						
		Sept 17 0·01	*Sept 24* 0·10†	*Mean*		
Griseofulvin	0·1	32	10	21**		
o-Hydroxy-diphenyl	0·1	73	57	65		
2, 2¹—Dithiopyridine—1, 1¹—dioxide	0·1	63	63	63		
Control	—	71	81	76		
1957. Fungicides applied Sept 2 and 18						
		Sept 2 nil	*Sept 5* 0·25	*Sept 9* 0·69	*Sept 18* nil†	*Mean*
Griseofulvin	0·05	3	43	54	12	28·0
Control	—	46	65	71	40	55·5
1958. Fungicides applied Sept 1						
		Sept 4 0·69	*Sept 9* 1·31	*Sept 14* 1·31†		
n-Dodecyl-guanidine acetate	0·09	97	—	—		
Griseofulvin	0·1	35***	54	54*		
Petroleum white oil emulsion	5·0	90	—	—		
Control	—	93	71	73		

* Significantly different from control at $P = 0{\cdot}05$. ** at $P = 0{\cdot}01$. *** at $P = 0{\cdot}001$.
† Rainfall in inches since spray application.

volume with a mobile tractor-drawn power machine with a triple-nozzle hand lance. In each year the trial was laid out in the form of a randomized block design, with single-tree plots, to permit statistical analysis. An adequate and fairly uniform inoculum of the disease was provided each season, by artificial infection of several fruits per tree with *S. fructigena* two or three weeks before the start of the experiment.

To assess the performance of the fungicide sprays, two artificial wounds were made in the skin of each of five fruits per tree, by means of a special instrument resembling a cork-borer with a cut of limited depth (Byrde, 1952b), which was sterilized at regular intervals. The number of wounds showing brown rot infection was assessed after five or six days: the presence of the fungus could be readily confirmed by the subsequent appearance of the typical buff-coloured conidial pustules. This procedure of artificial wounding was repeated at intervals of a few days as required. The results of the 1956, 1957 and 1958 trials are summarized in the Table. For statistical analysis, an angular transformation was used.

DISCUSSION

The results show interesting features: firstly, several compounds known to be highly toxic to the brown rot fungus failed to provide any control of the disease. This was probably due to the fact that the artificial wounding followed the fungicide treatment, and thus removed the fungicide deposit, just as would occur with a natural injury.

It is therefore noteworthy that the applications of griseofulvin were followed by a reduction in disease incidence in each of three seasons, and it seems reasonable to speculate that the compound may be acting systemically, at least in a localized manner. Its systemic properties were first reported by Brian, Wright, Stubbs and Way (1951) and subsequent work, both chemical and biological, has amply confirmed these findings (Crowdy, 1957; Rhodes, Crosse, McWilliam, Tootill and Dunn, 1957). A preliminary bio-assay of apple tissue immediately beneath the skin, from trees which had been sprayed with griseofulvin in 1958, indicated the presence of low concentrations of the compound. The degree of disease control appeared to decrease after a few days in two of the three seasons of the field trials. Further studies are being undertaken on the mode of action of griseofulvin against *S. fructigena* and its possible use against brown rot on plums.

SUMMARY

In each of the three seasons, 1956, 1957 and 1958, applications of griseofulvin (0·05 or 0·1 per cent) to Laxton's Superb apple trees were followed by a significant reduction in the infection of fruit injuries by the brown rot fungus, *Sclerotinia fructigena*.

The assistance of Miss M. Marlow and Mr. C. W. Harper is gratefully acknowledged.

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DOCKING DISORDER

by A. J. GIBBS

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AN abnormal condition of sugar beet was first noted in crops growing on farms around Docking, Norfolk, in 1948. The trouble is not confined to Norfolk, and in 1958 affected sugar beet were reported from places in Lincolnshire, Shropshire, Suffolk, and Yorkshire. Symptoms are similar to those of acid soil injury, but "Docking disorder", as the condition has been named, occurs on sandy soils with pH value above 6·5.

Leaves of affected sugar beet (or mangolds) are smaller than usual and often show signs typical of nitrogen or magnesium deficiency, or both. The leaves of the worst plants are thick and cupped, giving the whole plant a xeromorphic appearance.

Roots, too, are affected. The taproot may be only an inch or two long, or it may be killed. The main laterals often thicken to make a "fangy" root. Sometimes the taproot, the main laterals, or both, grow horizontally for some inches below the soil surface (Plate 1, 1).

The taproot or the main laterals are characteristically covered with a "beard" of dead or dying rootlets. After heavy rain fresh rootlets are produced but these soon stop growing and swell at their tips. Even though they no longer elongate, they still produce root hairs, and rootlets become club-shaped and almost covered with root hairs (Plate 1, 3). Finally the rootlet withers and dies. These symptoms resemble those caused by some toxic compounds (Åberg, 1957; Pollock, Goodwin and Greene, 1954).

When growing in soils giving affected sugar beet and mangolds, wheat and carrots are also affected. Carrots are of normal shape but small, and produce fewer "bolters" than unaffected carrots.

The incidence of Docking disorder varies from year to year, and was most serious and prevalent in 1948, 1953 and 1958. The disease reappears in exactly the same patches every year. Soil from such patches in different localities is similar, and differs in four main properties from nearby soil in which beet grow normally. It has **1**, a higher coarse sand content; **2**, a lower clay content; **3**, a lower organic matter content; and **4**, a lower base exchange capacity. A typical example of a soil analysis is given below.

Analysis of Soils from Docking, Norfolk

	2mm–200μ	200–20μ	20–2μ	2μ	Organic Carbon	Base Exchange Capacity*	pH†
	per cent	*per cent*	*per cent*	*per cent*	*per cent*		
Good soil ..	43	34	7	14	0·59	6·9	7·7
Bad soil ..	66	25	3	5	0·30	3·3	7·6

* Base exchange capacity—milliequivalents per 100g soil.
† The pH of a mixture of 2 parts of m/100 $CaCl_2$ and 1 part of soil.

With such a low clay and organic matter content the soil is structureless and slakes completely when moistened.

Fungi and nematodes have been isolated from the roots of affected beet, but they do not differ either in numbers or species from those isolated from the roots of unaffected beet. No virus has been detected by inoculating sap from affected roots on to *Chenopodium amaranticolor*. Affected beet taken from the field, replanted into pots of John Innes compost and kept in the glasshouse, recover completely and the new leaves and roots show no symptoms.

Beet grown from seed sown in pots of affected soil grew poorly and, as in field crops, their rootlets died. When sown in affected soil mixed with an equal weight of compost, the beet grew as well as in compost alone or in unaffected soil from the field. However, sterilizing the affected soil in an autoclave for half an hour only slightly increased growth.

These results, and those of other workers (Buxton, 1957; Gates, 1955, 1956; and Skinner, 1956), suggest that the disorder is not caused by a pathogen, but is a direct result of some unusual physical or chemical condition in the soil.

I am indebted to Mr. C. L. Bascomb for the results of the soil analyses, and to Dr. R. D. Winslow, who investigated the nematode populations.

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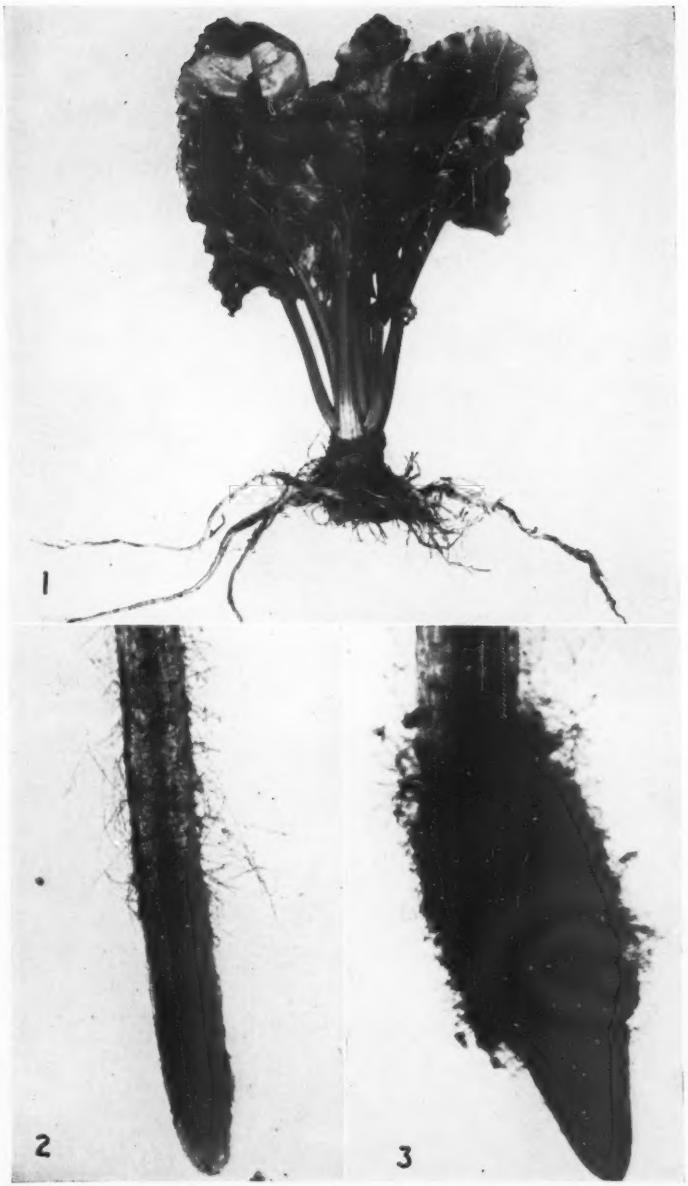
DOCKING DISORDER



Photos: Rothamsted Experimental Station

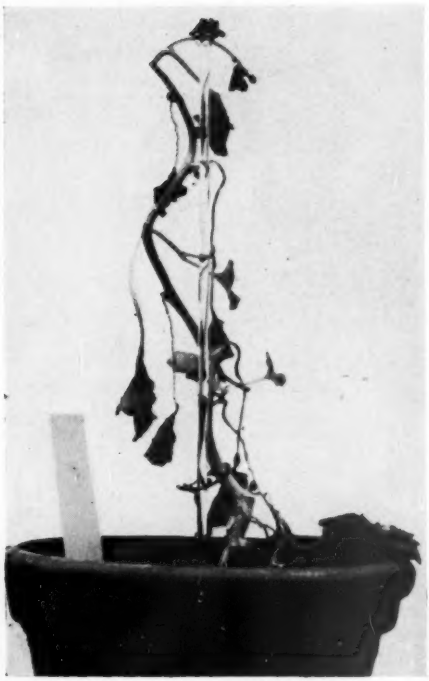
1. Affected sugar beet plant.

2. Healthy root-tip.

3. Diseased root-tip.

PLATE I

FUSARIUM WILT OF MELON (see p. 96)



1. *Left:* Wilted plant (var. Tiger) from inoculation experiments in glasshouse.

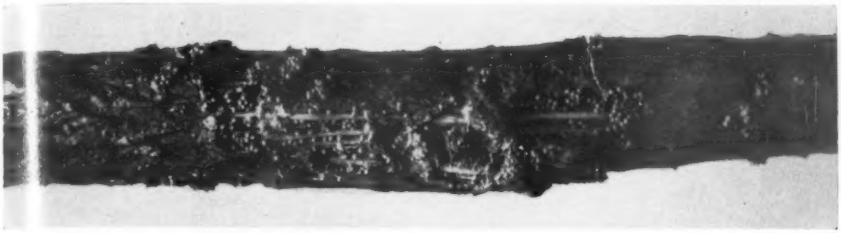
2. *Above:* Pieces of main root of a wilted plant cut to show discoloration of vascular tract.

Photos: Rothamsted Experimental Station

3. Wilt caused by *Fusarium oxysporum f. melonis* on melons in the field (var. Tiger).

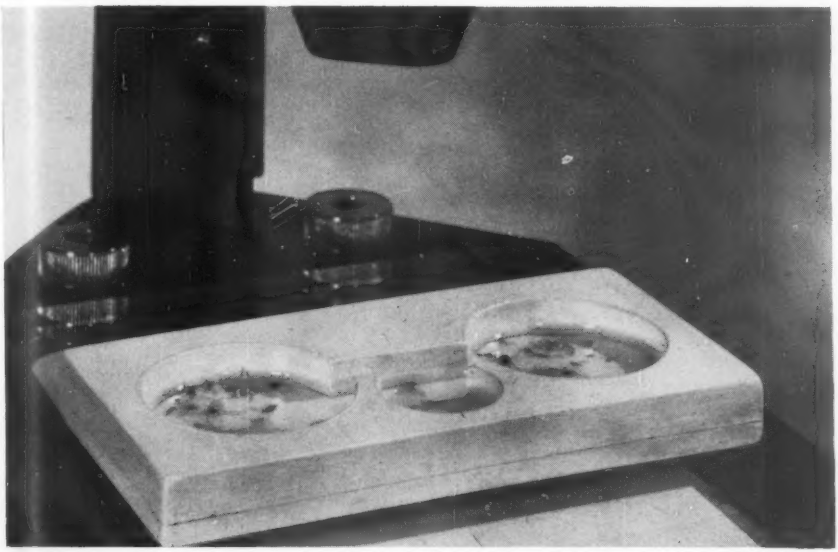
PLATE II

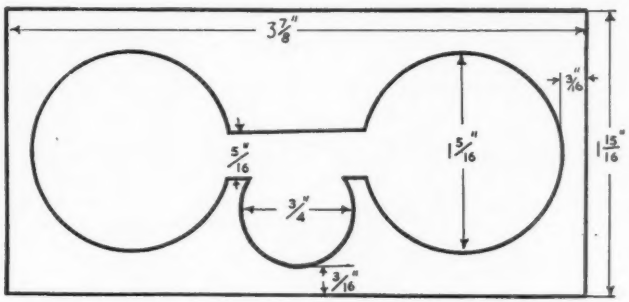
PERITHECIAL STAGE OF APPLE CANKER (see p. 113)



1. Perithecia on current season's shoot of Laxton's Superb (×4).

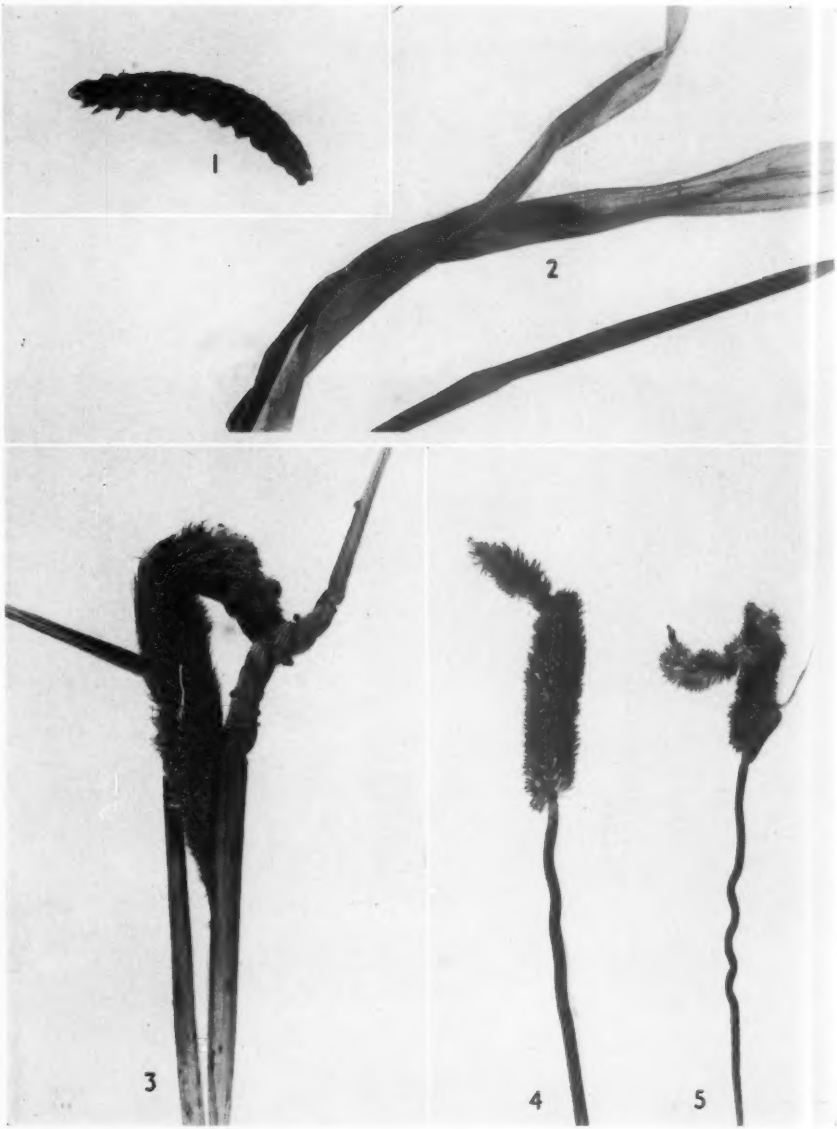
SEPARATING TRAY FOR SMALL INSECTS (see p. 114)





2. Tray in use under binocular microscope, and dimensions.

PLATE III



1. *Amelia paleana*, mature caterpillar.
2. Pupa *in situ*.
3. Timothy seed head with distal end trapped within larval web.
4. Head distorted after being trapped within web.
5. Head showing damage caused by caterpillars feeding on seeds.

PLATE IV

A TORTRICID CATERPILLAR AFFECTING TIMOTHY SEED CROPS

by R. GAIR
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BRED strains of timothy grass, *Phleum pratense*, are grown extensively for seed production in the East Midlands. Annual inspections by N.A.A.S. officers indicate that the most prevalent insect pests of timothy are various graminaceous aphid species and timothy flies (*Amaurosoma* spp.).

In June 1951, seed crops of S.48 timothy at Saxby and Saxilby, Lincs. (Lindsey) and at Lowesby, Leicestershire, were attacked by large numbers of caterpillars, which were subsequently identified by Mr. J. D. Bradley of the British Museum (Natural History) as larvae of the tortricid moth *Amelia paleana* (Hübner). No further cases were seen in the East Midlands until the summer of 1958, when S.48 seed crops were found heavily infested near Wellingore, Lincs. (Kesteven) and at Tixover, Rutland. All attacked fields in both years were in their fourth or fifth harvest season, and were sited on low-lying, poorly-drained soils.

Observations on the life history were made chiefly on the Wellingore field during 1958. The caterpillars (Plate IV, 1) are almost an inch long when fully grown. Although the basal body colour is stated to vary a good deal from grey to black, all specimens noted in the East Midlands have been extremely dark. Prominent white tubercles are scattered over most of the body segments. Each caterpillar normally lives within a web formed by spinning together either the edges of the topmost leaf at the junction of blade and ligule, or of adjacent leaves from the same or separate plants. It feeds in the usual tortricid manner by stripping the upper epidermal and mesophyll tissue of the leaf within the web area. That portion of leaf distal to the feeding region usually turns yellow. Attacks in the field are easily recognizable, since the differential growth rate of leaves joined together by the web results in their apices pointing in all directions. The grass blades often become rolled and sharply bent; while the tip of the emerging inflorescence may become trapped within the larval web, and as the stem elongates the seed-head forms a characteristic loop (Plate IV, 3). Usually the head frees itself and grows normally but sometimes it becomes greatly distorted (Plate IV, 4 and 5). At Wellingore in 1958 several caterpillars were seen stripping seeds from the trapped inflorescences.

Full details of the morphology of each instar and bionomics in Sweden are given by Lindroth (1932), with whose account the Lincolnshire observations closely agree. Adult moths (illustrated by Bradley and Martin, 1956) are on the wing throughout July and August. Small numbers were swept from the Wellingore field on June 30, 1958 and thereafter until early August. Eggs are laid in batches on the upper surfaces of grass blades situated close to the soil, the larva hatches a week later, then spends the winter months within the lower leaf sheaths. In spring it moves upwards to feed in the manner described above, and when mature usually migrates from its last feeding position and constructs a cocoon between two fresh leaves. The pupa (Plate IV, 2) is dark brown in colour and the pupal stage lasts approximately fourteen days, with a range of ten to seventeen days for laboratory-bred material.

In Scandinavia and Finland the caterpillar ranks as a serious pest of timothy crops. Lindroth (1932) mentions a figure of 50 per cent loss of productivity on some Swedish farms during the period 1923–32, presumably referring to timothy

pastures and meadows. He also reports serious loss of seed yield, with added difficulties in harvesting caused by the matted, webbed foliage.

Although the moth is fairly abundant in most other European countries, reports of damage to timothy and other crops are very few. In this country adult moths have been frequently recorded (Stainton, 1859; Meyrick, 1928), and the larvae observed feeding on a wide variety of grasses and broad-leaved plants (Ford, 1949). The attacks in 1951 and 1958 in the East Midlands did not materially affect yield of timothy seed in spite of a fairly dense larval population (for example, one to three per square yard at Wellingore). It seems, however, that *Amelia paleana* constitutes a potential menace to timothy seed production in Great Britain, particularly in low-lying areas to which the moth seems attracted.

Thanks are due to Mr. V. Stansfield, of Rothamsted, for the photographs.

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THE OCCURRENCE OF *FUSARIUM* WILT OF MELON IN BRITAIN

by E. W. BUXTON

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IN August 1956 and 1957, melon plants, *Cucumis melo* L., variety Tiger, were found wilting and dying under cloches in a commercial garden at Chorleywood, Herts. Symptoms were similar to those previously reported for *Fusarium* wilt of melon from the United States (Leach and Currence, 1938), Canada (Reid, 1958) and elsewhere. In Britain, a wilt of melon associated with *Fusarium* sp. was referred to by Bewley (1923) and more recently has been reported occasionally (Moore, 1943). The species of *Fusarium* concerned was not determined, nor were any pathogenicity experiments made. In the recent outbreaks pathogenicity of the *Fusarium* isolates has been proved. The leaves of the affected plants were pale yellow between the veins, later turning to a uniform bright yellow as they completely wilted. Plants became slightly stunted and the fruits only reached about an eighth of their normal size (Plate II, 3). The vascular tracts of roots and stems from affected plants were bright orange-red (Plate II, 2) and, although most of the wilted plants showed no external symptoms of root damage, a few that were severely affected had a root cortex that had turned brown and could be easily removed.

Fusarium oxysporum was consistently isolated from the vascular tissue of both stems and roots of wilted plants and the pathogenicity of ten isolates was tested in a heated glasshouse (17°–25°C). Four melon varieties, together with cucumber and vegetable marrow plants, were grown from seed and transplanted into 10-inch pots of John Innes potting compost. Suspensions of spores of a mixture of the ten isolates were then poured over the surface of the soil. Wilt symptoms appeared within 2½ months, and after 3½ months they were as severe as those seen in the field (Plate II, 1). The results were:

Host	*Variety*	*No. wilted*	*Notes on Symptoms*
Melon	Best-of-All	2/5	Vascular browning very slight
Melon	Blenheim Orange	6/6	Vascular system bright orange
Melon	Hero of Lockinge	5/7	Wilt slow to develop
Melon	Tiger	6/6	As seen in field
Cucumber	Not known	0/6	Healthy
Vegetable marrow	Not known	0/6	Healthy

Control plants, uninoculated, remained healthy.

These results show that the isolates were highly virulent to three of the melon varieties, mildly virulent towards variety Best-of-All, but had no effect on cucumber or vegetable marrow. With this evidence of specific pathogenicity, the *Fusarium* can be assigned to *F. oxysporum* Fr. f. *melonis* (Leach and Curr.) Snyd. and Hans. It was consistently re-isolated from all fragments of vascular tissue taken from each diseased plant at the end of the experiment.

In common with other soil-borne *Fusarium* wilts, this disease can best be avoided either by abandoning the soil for melon cultivation, or by growing wilt-resistant varieties (Reid, 1958).

SUMMARY

From wilted melon plants (*Cucumis melo* L.), at Chorleywood, Herts, in 1956 and 1957, pathogenic isolates of *Fusarium oxysporum* Fr. f. *melonis* (Leach and Curr.) Snyd. and Hans. were consistently isolated. The fungus wilted four melon varieties but had no effect on cucumber or vegetable marrow.

I thank Miss J. Ives, N.A.A.S., Trumpington, Cambridge and Mr. A. E. Waterfield, Horticultural Officer, N.A.A.S., Brickendonbury, Herts, for drawing my attention to the diseased plants, and Mr. V. Stansfield for taking the photographs.

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CONTROL OF BULB SCALE MITE WITH ENDRIN

by C. A. COLLINGWOOD
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MITE infested bulbs of the variety "King Alfred", which were infested with *Tarsonemus laticeps* Halb., were boxed on October 16, 1957, and left out of doors. They were brought into a heated glasshouse (minimum temperature 55°F.), on January 10, 1958, and were treated as follows on January 13, 1958:

Frosted overnight (Grass. minimum temperature 20°F.).
Fluoroacetamide, 0·1 per cent drench.
Endrin, 0·1 per cent emulsion plus 0·02 per cent dioctyl–sulphosuccinate drench.
Demeton-methyl, 0·05 per cent drench.
Control—water only.

About two pints of the diluted insecticide were applied to each box of 24 bulbs with a fine rose watering can. Each treatment was duplicated. The bulbs were examined on March 26, 1958, with the following results:

Treatment	No. of Bulbs	Percentage with Foliage Symptoms and Mite Colonies	Percentage of Dissected Bulbs with Symptoms	Mean Height of Foliage (*inches*)
Frost	42	67	85	14·8
Fluoroacetamide	45	61	85	11·6
Endrin	43	5	80	16·0
Demeton—methyl	45	80	85	10·8
Control	44	75	95	11·9
S.E.	—	6	8	2·5
Significant Difference (p = 0·05)	—	19	NS	3·5

There is some circumstantial evidence from this work, and that of other observers, that most of the foliage distortion and flower suppression occurs through the great increase of mite activity which follows after the bulbs have been brought into heat. A high proportion of the bulbs in each treatment contained live mites at the end of the observations, but feeding on the foliage on the endrin-treated boxes had been almost totally suppressed, while growth was vigorous and clean. The frost treatment did not reduce mite populations but foliage growth was more vigorous than in the control boxes. This supports earlier unpublished work by B. A. Cooper that a short frost treatment may in certain circumstances result in enhanced growth and flowering through a temporary check to mite activity.

In experiments described by Harrison (*Plant Pathology*, 1956, **5**, 127–9), much the same effects seemed to have occurred, since none of the chemical treatments that were used appeared to have eradicated the mite infestation, but nevertheless their use, especially after forcing had begun, was associated with considerably better flower production. In the above trial, the bulbs were not of flowering size but there appears sufficient indication to suggest that an endrin drench applied when the bulbs are brought in for forcing could provide an effective control.

The use of demeton-methyl appeared by contrast to have resulted in increased damage and larger populations of scale mite. This is considered to have been partly due to the destruction of springtails and predatory mites which were present in some abundance on the control series.

YELLOW MOSAIC OF BROCCOLI IN NORTH-EAST ENGLAND, 1953-57

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IN our first account of yellow mosaic on broccoli in Northumberland (Croxall, Gwynne and Broadbent, 1953) we attributed this disease to the turnip yellow mosaic of Markham and Smith. Broadbent and Heathcote (1958) have now shown that the TYM(E) virus of Markham and Smith is serologically related to, but differs antigenically from, the Northumberland virus, which they have named TYM(N). They have also shown that TYM(N) produces more severe symptoms in cauliflower, cabbage and Brussels sprouts than does TYM(E). The TYM(N) virus also infects cruciferous weeds, so that these may also serve as sources of infection for commercial crops.

The principal known vectors, flea beetles, are most abundant in sunny weather in April and May, as was shown by Newton (1928) and Moreton (1945). Newton also reported that a mass of young adults might appear any time between the end of July and the end of August. We have found flea beetles present in brassica crops as early as March and as late as November during mild weather. Thus, in broccoli, the crop most seriously damaged by the disease, spread may occur at any time after the seedlings emerge until the flea beetles hibernate in the autumn, and again in spring when overwintering flea beetles become active. Infected plants with only slight symptoms are severely injured or killed by frost, and this increases the losses caused by the disease.

The problem in the North-east was to control the disease in broccoli; not only to restore the profitability of the crop on those holdings where the disease was epidemic in 1953, but also to reduce the risk of spread into areas where it was not yet established. To have put down replicated trials on commercial holdings would have involved leaving untreated control plots which might have acted as sources of infection, and thus defeated efforts to break the cycle of infection and restrict spread. It was therefore decided to employ survey methods, and as far as possible to follow the course of the disease on a number of holdings which had no other market garden adjoining them which could serve as a source of infection, but where the disease was severe in 1953. On some of these holdings it was possible to introduce tentative control measures. Principal objects of the work were to investigate the effects of seedbed infection, proximity to other infected crops, exposure of site, control of the vectors in the seedbed and after planting out and, where possible, roguing of infected plants. The centres chosen were as follows:

1. HEPSCOTT, near Morpeth, Northumberland, about 6 miles from the coast. A large-scale market garden surrounded by farms.
2. AMBLE, Northumberland, on the coast. A small market garden, partly enclosed by walls, and overlooking the sea.
3. MORPETH, Northumberland, 9 miles from the coast. A market garden on the southern edge of the town.
4. RYHOPE, near Sunderland, Durham, on the coast. A market garden on the outskirts of the village with land extending to the cliffs.
5. SADBERGE, Durham, about 3½ miles N.E. of Darlington. A market garden with scattered fields among farm crops.

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* Now at N.A.A.S., Woodthorne, Wolverhampton.
† Now at N.A.A.S., Bryn Adda, Bangor.

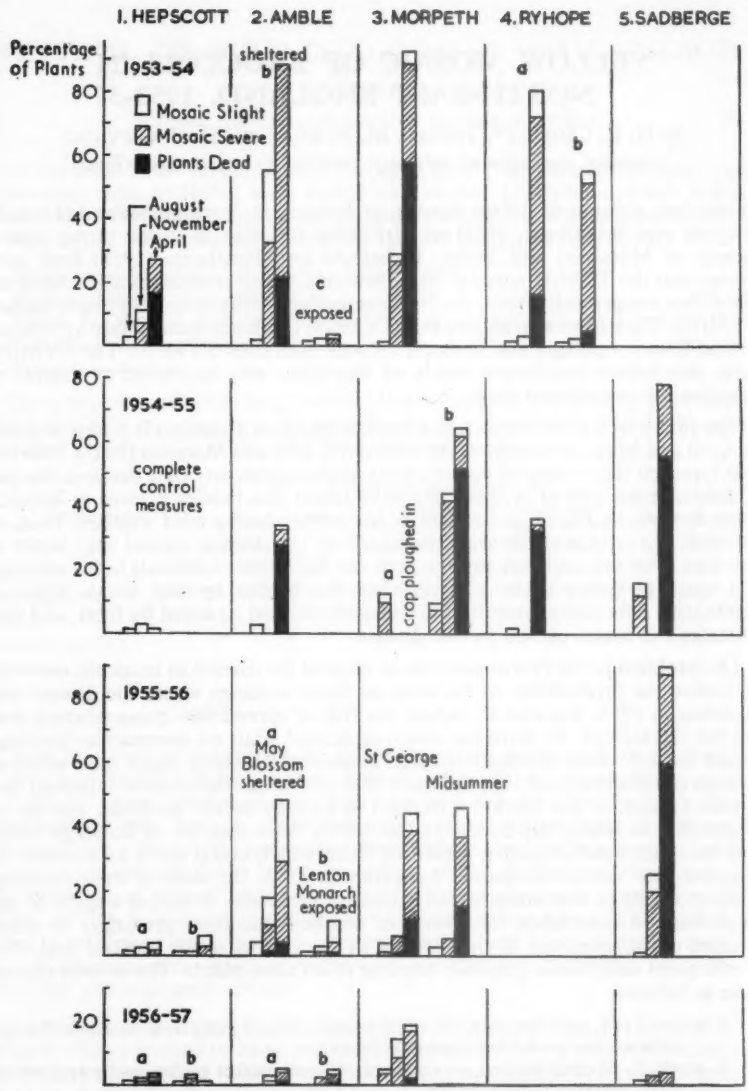

Fig. 1. Percentages of broccoli plants affected by yellow mosaic in August, November and April, in each of the seasons 1953–54 to 1956–57, at the five survey centres.

The survey was carried out on broccoli crops at the same five centres in each of the four seasons, 1953–54, 1954–55, 1955–56, and 1956–57. The crops were surveyed in August after the plants were established, and notes were then made on the proximity of any infection source. Whenever possible the crops were again surveyed in late autumn (November) and finally shortly before cutting in the following May. On each occasion counts were made on sixteen random

samples of fifty plants in each field; the plants, or the mosaic symptoms, being classified as: A. *Healthy* (free from yellow mosaic symptoms); B. *Slight* (showing slight mosaic symptoms); C. *Severe* (showing mosaic symptoms severe enough to detract from market value); D. *Stunted* (showing severe mosaic symptoms *and* stunted growth); or E. *Dead* (following mosaic infection). The mean percentages of the plants in categories B, C + D, and E at the three times of inspection on most of the sites at the several centres each year are shown by the histograms in Fig. 1. The final assessments for all sites just before cutting are given in more detail in Tables 1, 2, 3, and 4. All the varieties designated as "Local Strain" in the Tables were of the St. George type.

SURVEY IN 1953–54

In this year it was possible to introduce only a limited number of control measures as the growers' plans had largely been made, and in some cases the seed had been sown when the survey began.

At centre 1, where 80 per cent of the previous crop had been infected, it happened that the plants were obtained from another holding where the disease had been absent. After planting out, the nearest source of infection was a Brussels sprout crop containing less than 1 per cent of infected plants, 20 yards to the west.

At centre 2, where losses had been particularly heavy in 1952–53, the seedbeds were sprayed fortnightly with DDT emulsion from the time of emergence until planting out. The plants at this centre were distributed between three sites: (2a) a small garden separated from the remainder of the holding by a hedge, a roadway and then a wall, this site being about 15 yards from the nearest source of infection; (2b) a walled garden adjoining autumn cauliflowers and 15 yards north of summer cauliflowers, in both of which about 10 per cent were infected plants; and (2c) on a west-facing exposed slope about 100 yards from the infected cauliflower crops.

At centre 3 the seedbed adjoined a summer cauliflower plot in which about 10 per cent of the plants were infected. After planting out, the crop was separated from cauliflowers having a 5 per cent infection, by a three-yard-wide roadway.

At centre 4 there were two sites. The plants for site 4b were grown in a seedbed 15 yards west of a cabbage crop in which less than 1 per cent of the plants were infected, and the site itself was between two spring cabbage crops, which had less than 1 per cent of their plants infected. Site 4a, in which the plants were

TABLE 1

Percentages of Affected Plants Just Before Cutting, 1953–54

Centre and Site	Variety	Healthy Plants	Plants with Yellow Mosaic Symptoms			
			Slight	*Severe*	*Stunted*	*Dead*
1	St. George	74·1	0·1	3·2	6·4	16·2
2a	St. George	75·0	0	10·5	14·5	0
b	St. George	15·0	0	12·0	52·5	20·5
c	St. George	98·3	0·1	0·7	0·8	0·1
3	St. George	9·0	3·2	16·8	13·0	58·0
4a	Local Strain ..	19·5	7·5	26·0	32·0	15·0
b	Local Strain ..	44·6	3·2	22·0	26·0	4·2

grown in a garden separated from the main holding by a wooden fence, adjoined the south end of one of these spring cabbage crops.

The weather during June, 1953 was cool and dull and there was little flea beetle activity. Only at centre 3 were occasional infected plants seen in the seedbed. The first records in August (Fig. 1) confirmed that in this season seedbed infection was absent or very slight. The differences in build-up at the several centres were, therefore, probably attributable to differences in proximity to sources of infection after planting out, and to differences in the degree of flea beetle activity. It would be expected that the more sheltered sites tended to favour flea beetle movement. This was borne out by the rapid build-up of the disease in the two most sheltered sites 2b and 3, which were, however, also adjacent to infected crops. The importance of shelter and proximity to infection after planting out was again indicated by the final counts at centre 2, where all the plants came from the same seedbed. Here, where the plants were put out adjoining infected cauliflowers in a walled garden (2b) the crop was almost a complete failure; with isolation of 15 yards in a more exposed position (2a) one quarter of the crop was affected; while 100 yards away on a slope exposed to the wind (2c), infection was negligible. At the inland centres 1 and 3, the percentages of infected plants killed were much higher than at the coastal centres 2 and 4, where, no doubt, there was less frost.

SURVEY IN 1954–55

At centre 1 in 1954 it was possible to introduce a complete programme of control measures. The seed was treated with a BHC preparation, and sown 20 yards away from the nearest infected crop; the seedlings were sprayed fortnightly with a DDT emulsion before planting out. The plants were put into a field in which there were no other brassicas—although there was an infected cauliflower crop in an adjoining field. Immediately after planting out, the hedgerows and headlands were sprayed with DDT (4 pints 18 per cent DDT emulsion in 40 gal water), and the crop itself was sprayed twice with this at 40 gal per acre. With the assistance of Mr. J. Haywood, the County Horticultural Officer, all plants showing mosaic symptoms (1·1 per cent of the total number) were rogued out after the November counts.

At centre 2 the seedbed was 20 yards from the nearest source of infection, but the plants had to be put out alongside a crop of Brussels sprouts in which there was slight infection.

At centre 3 both the seedbed and the subsequent crop adjoined severely infected cauliflowers. At site 3a the crop was ploughed up in October.

TABLE 2

Percentages of Affected Plants Just Before Cutting, 1954–55

Centre and Site	Variety	Healthy Plants	Plants with Yellow Mosaic Symptoms			
			Slight	*Severe*	*Stunted*	*Dead*
1	St. George	99·9	0	0	0·1	0
2	Snow White ..	67·1	1·1	0·5	2·6	28·7
3b	Midsummer ..	36·6	1·6	2·6	6·7	52·4
4	Local Strain ..	64·8	0·6	1·3	1·1	32·2
5	Local Strain ..	23·6	0	0	23·2	53·2

At centre 4 the seedbed was again in the garden adjoining the main holding. The plants were put out adjoining Brussels sprouts, in which no infected plants were seen.

At centre 5 the seedbed adjoined broccoli and cabbage, and the crop was planted 100 yards from spring cabbage.

Although the weather in June, 1954 was cool with about average rainfall the August counts indicated that seedbed infection was of some importance in the 1954–55 season. At centre 3 there was over 10 per cent infection; at centre 5 over 15 per cent; while at other centres there was 1 per cent or less (Fig. 1). It was possible to carry out the November counts only at centres 1 and 3. At centre 3a the variety St. George, which adjoined a heavily infected cauliflower crop, was so seriously affected that the grower ploughed it up in November, while two-thirds of the remaining crop of the Midsummer variety (3b) was infected by cutting time. Warm sunny spells in late August and early September, and mild sunny weather in the last half of the following April may have provided periods favourable to flea beetle activities in the crops. Build-up of infection was less at centres 2 and 4, but was still considerable. It was encouraging, however, that at centre 1 there was only 1 per cent infection in November, and after roguing there was almost no further spread up to cutting time.

SURVEY IN 1955–56

In this season all the seed except that at centre 5 was treated with a *gamma*-BHC anti-flea-beetle preparation. At centre 1 the seedbed was also sprayed with DDT emulsion. There was no source of infection near the seedbed, but the crop was planted out 50 yards south-east of a cauliflower crop with slight infection. The crop was twice sprayed with DDT emulsion.

At centre 2 the seedbed was isolated, and it was sprayed with DDT emulsion. Two varieties, May Blossom and Royal Oak, were planted in an adjoining garden screened on the east by a beech hedge, and on the west by a wall (site 2a). Two other varieties, Lenton Monarch and St. George, were planted on an east-facing slope overlooking the sea (site b). Cauliflower crops containing a few infected plants adjoined both plots. There were just over 2,000 plants at each site, and a record was kept for every individual plant.

TABLE 3

Percentages of Affected Plants Before Cutting, 1955–56

Centre and Site	Variety	Healthy Plants	Plants with Yellow Mosaic Symptoms			
			Slight	*Severe*	*Stunted*	*Dead*
1	Royal Oak	95·9	2·8	1·3	0	0
	Midsummer ..	93·7	4·4	1·1	0·8	0
2a	May Blossom ..	52·5	19·7	16·7	8·3	2·8
	Royal Oak	65·7	16·0	9·4	7·2	1·7
b	Lenton Monarch ..	91·0	6·5	1·5	0·8	0·2
	St. George	96·7	2·0	0·6	0·7	0
3	St. George	56·0	5·5	13·0	13·9	11·6
	Midsummer ..	53·7	8·3	10·8	11·4	15·8
5	Local Strain ..	10·0	2·0	8·0	20·0	60·0

At centre 3 the seedbed was in the field that had carried the previous year's broccoli crop. The plants were set out alongside savoys which showed no infection, on a site sheltered by hedgerows and a wall.

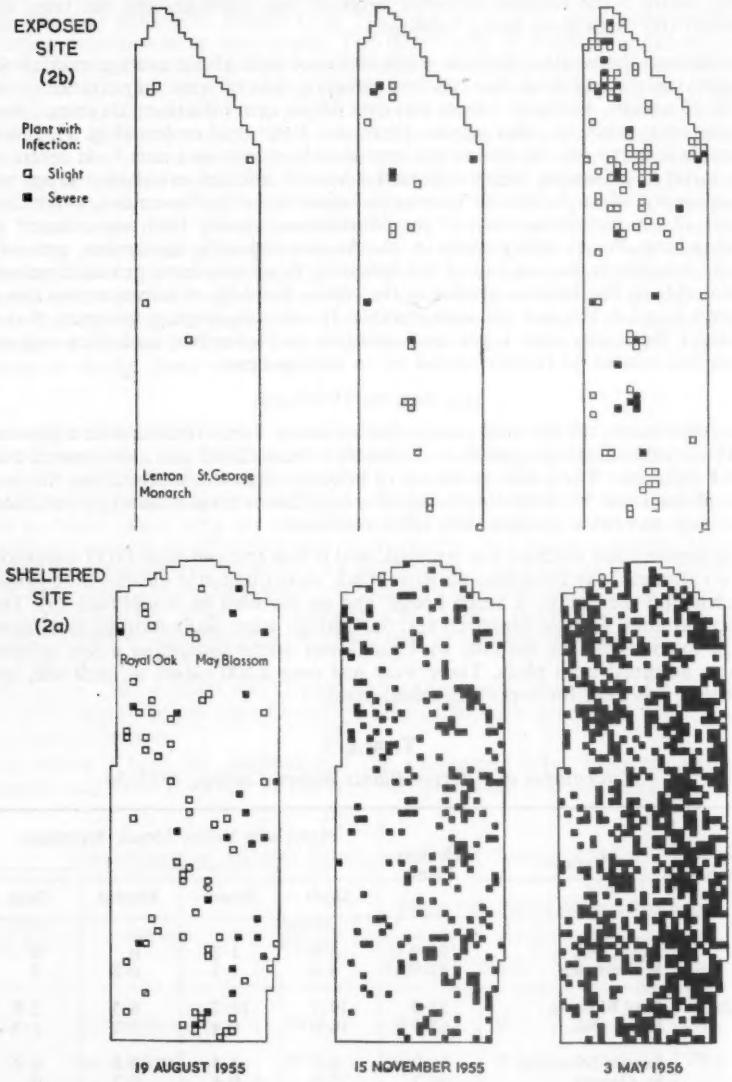

Fig. 2. Spread of yellow mosaic on exposed and sheltered plots at centre 2, Amble, Northumberland, 1955–56.

At centre 4 no records were made in this season. At centre 5 no inspection was made in August, but the seedbed was reported as being near a cauliflower crop. The site for planting out adjoined infected autumn cauliflowers.

The weather in June, 1955 was again cool with about average rainfall, but no seedbed infection was seen at any of the centres when August inspections were made. At centre 1 no infection was seen until November, and it was then very slight. There was a little build-up before cutting but the losses were negligible (Fig. 1).

There was a great difference in the course of the disease at the two sites at centre 2. This could not be attributed to differences in varietal susceptibility. No significant differences in such susceptibility could be detected in variety trials carried out in 1954; and the variety St. George, which was so little affected on the exposed site 2b, suffered heavy losses elsewhere in 1955–56, as well as in previous seasons. Fig. 2 shows the distribution of infected plants on each date of inspection on part of the exposed plot 2b, and on the sheltered plot 2a. On the exposed plot there were less than four infected plants per thousand in August; there was little build-up by November; and the spread by cutting time in the following May was mainly along or across rows from previously infected plants. On the sheltered plot there was more infection present in August than there was on the exposed plot by cutting time. This was almost certainly not due to infection in the seedbed, as all the plants for the two plots came from adjoining rows in the bed. Moreover the variation in intensity of symptoms indicated that secondary infection had occurred. Although in the sheltered plot some of the infected plants could be seen to be in groups there was a much wider distribution over the plot as a whole, than there was at the exposed site by the end of the season.

At centre 3, where the site was sheltered by hedgerows and a wall, the incidence of the disease was similar to that on the sheltered site at centre 2. There was little build-up of infection in the summer and autumn, but very quick spread before cutting time. At both centres, although no infection was seen in the seedbeds, the number of infected plants present in August indicated that a few may have been infected when planted out. At centre 5 a quarter of the crop was infected in November, and by cutting time it was almost a complete failure.

The rapid build-up of the disease in the spring of 1956, particularly at the sheltered site, may be partly associated with the 1955 summer weather. Exceptionally dry and sunny spells from July to September favoured the increase of flea beetles, and it is probable that more survivors than usual emerged during the bright days which occurred in late March and early April, 1956.

SURVEY IN 1956–57

In 1956 the seed at all centres was treated with BHC anti-flea-beetle dust. At centre 1 the seedbed adjoined a cabbage plot but this did not show any infection. The plants were set out in two different fields, each about 20 yards from the nearest source of infection. On site 1b all infected plants seen were removed on March 1.

At centre 2 the seedbed was sprayed with DDT emulsion, and the nearest source of infection was 50 yards away. After planting out, the varieties St. George and Lenton Monarch were separated from May Blossom and Royal Oak by a stone wall. A summer cabbage plot adjoined the Royal Oak, but no infection was seen in it. Lettuce adjoined the other planting and the nearest infection was 50 yards away.

At centre 3 the seedbed was near savoys and spring cabbage, but these did not show any infection. After planting out the crop adjoined cabbage in which there were four infected plants.

At centre 5 the seedbed was completely isolated from any brassica crop. The crop was planted out near cabbage, and this did not show any infection.

TABLE 4

Percentages of Infected Plants Just Before Cutting, 1956–57

Centre and Site	Variety	Healthy Plants	Plants with Yellow Mosaic Symptoms			
			Slight	*Severe*	*Stunted*	*Dead*
1a	Midsummer ..	97·5	0·5	0·8	1·0	0·2
b	Midsummer ..	99·8	0·2	0	0	0
2a	St. George	97·7	0·7	1·0	0·3	0·3
	Lenton Monarch ..	97·0	1·2	0·3	1·2	0·3
b	Royal Oak	96·2	1·3	0·7	0·5	1·3
	May Blossom ..	97·7	0·3	0·3	0·7	1·0
3	Midsummer ..	82·3	1·7	5·2	8·5	2·3
5	St. George	97·5	0·1	0·6	1·8	0

The outstanding feature of the 1956–57 season was the low level of infection at all sites. This cannot be entirely attributed to the increasing efficiency of the control measures employed. Seed treatment and isolation of seedbeds may have played some part in reducing the amount of infection at planting time. However, by August at centre 3 there was 4 per cent infection in the crop and, to judge by previous years, this was quite sufficient inoculum to start an epidemic. The explanation probably lies in the weather conditions. Although June was cool with about average rainfall, which was much the same as in the other years of the survey, July and August were exceptionally wet and dull months, so that the multiplication of flea beetles was probably much below that of the previous year. There would be fewer flea beetles to come out of hibernation; and March was dull at first, and later windy. Also the crop matured earlier, so that the final counts had to be made three to four weeks ahead of previous years, leaving less time for any late infection to show up.

TRIALS ON EFFECT OF BARRIER CROPS

In 1954–55 a replicated trial was carried out at Longbenton, Newcastle-upon-Tyne to test the efficacy of barrier crops in reducing spread of infection. The barriers of kale, barley or broad beans were as listed in Table 5; they were sown in a band 1-ft wide surrounding plots 13 ft by 20 ft 6 in. In July, broccoli plants, variety St. George, were set out in eight rows of four in each plot. There were four replications of each treatment. Two blocks were to the east and two to the west of a double row of broccoli plants inoculated with yellow mosaic. The plants in each plot were examined for infection in November and again in May; the mean percentages infected being given in Table 5.

Although these results indicate that barriers may restrict the spread of the disease, they cannot be regarded as conclusive as the level of infection in the control plots was barely 15 per cent. There were few flea beetles on the plots, and further experiments are needed under conditions more favourable to the vector. A similar experiment laid down in 1954 failed owing to insufficient spread from the infectors.

In 1956–57 a replicated trial was conducted at the same site to determine the effect, upon spread of the disease, of introducing infected plants in August, September, October and March. The little secondary spread that occurred was

TABLE 5

Effect of Treatments on Mean Percentage Infection

Treatments	Mean Percentage of Infected Plants	
	November 1955	*May 1956*
Control: no spraying or barriers	5·5	14·8
Crop twice sprayed with DDT emulsion	3·9	9·4
Barrier: 3 rows kale unsprayed	1·6*	3·1*
Barrier: 3 rows kale twice sprayed with DDT emulsion	1·6*	9·4
Barrier: 3 rows barley	1·6*	7·0*
Barrier: 3 rows broad beans	2·3*	3·1*
S.E.	±0·9	±2·9

* Significantly different from control ($p = 0·05$).

almost entirely in the plots in which infectors were introduced in August. The secondary infections became apparent in October following a short period of dry sunny weather, conducive of flea beetle activity at the end of September.

SUMMARY

A survey of the incidence and spread of yellow mosaic in broccoli was made on numerous crops at five centres in Northumberland and Durham over the years 1953–57. Beneficial effects of the progressive adoption of control measures were revealed by the survey. These methods included the isolation of seedbeds, treatment of seed with *gamma*-BHC dust, and spraying the seedbeds with DDT for the suppression of the flea beetle vectors. The amount of infection occurring after planting out was found to depend on the occurrence of sunny weather favouring flea beetle activity; on the proximity of infected brassica crops; and on the degree of shelter of the site. In exposed situations isolation of 20 yards effectively reduced spread, but in sheltered places isolation of at least 100 yards from heavily infected crops appeared to be needed. Spread of the disease was much faster within crops in gardens than within those in more exposed situations. There was an indication that spraying with DDT during periods of sunny weather in late summer may be useful on crops that are infected, or near to sources of infection, at that time. Plants only slightly infected before winter suffered severely from subsequent frost injury. Roguing-out of infected plants was found to be advantageous, and as little spread occurs during the winter, the best time for such roguing appeared to be in the spring, before the emergence of the flea beetles from their hibernation. In a randomized block trial carried out in 1954–55 three-row barriers of kale, barley or broad beans significantly reduced spread of the disease from infected to healthy plants.

We thank the growers whose co-operation made this survey possible, and also Mr. W. A. Davey for his assistance.

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EAR POPULATIONS IN CEREAL CROPS

Contribution from the Conference of Plant Pathologists, National Agricultural Advisory Service, compiled by A. G. Walker, N.A.A.S., Evesham

In the method recommended by the Disease Measurement Committee of the British Mycological Society (Moore, 1943), for the field assessment of percentage of ears affected by loose smut and other diseases, the limits of the lower categories were based on the long-assumed general average of one million ears per acre for cereal crops; fewer than one infected head in 50 sq. yards representing less than 0·01 per cent infection, and fewer than two heads per square yard, less than 1·0 per cent infection. In the inspection of cereal seed crops for certification, the Seed Production Committee of the National Institute of Agricultural Botany at first worked on the same assumption of one million ears per acre: mean counts of affected ears per 24 sq. yard quadrat (1/200 acre) being divided into 5,000, to give an estimate in the form 1 in X.

Systematic ear counts made in the course of a survey for eyespot in West Sussex in 1953 showed an average of 1½–2 million ears per acre in fifteen crops of wheat, and nearly three million in six crops of barley. Ear populations of a similar order were found by Dr. C. C. V. Batts in a number of counts at the N.I.A.B. about this time. Recognizing that a reasonably accurate standard figure for number of ears per acre is a prerequisite in many cereal disease assessment methods, and that the long-accepted average of one million heads per acre might well be too low in view of changes in cultural practice and varieties now grown, the Disease Assessment Committee of the Conference proposed a limited survey to check the present level of ear populations. With the co-operation of the N.A.A.S. Plant Pathologists, Crop Husbandry Officers, and Regional Trials Officers of the N.I.A.B., figures were obtained for wheat and barley, and to a less extent for oats, in various parts of England and Wales in 1954; and further figures, mostly for oats, were obtained in 1955.

A very simple survey method was employed. The counts were made in any cereal field that happened to be visited in the course of other work, without discrimination as to variety or level of cultivation. In a representative portion of each field, counts were made of the number of heads per measured yard of drill (ignoring small late tillers) at ten sites at random. The mean drill width was measured, and a note was made of whether in the observer's opinion and experience the crop was "heavy", "average" or "thin". The variety and locality were recorded. Other information was noted in some cases, but no attempt was made to correlate ear populations with manurial treatments or yields. These matters were beyond the scope of a small pilot survey.

The counts were made in the two years on twenty-two crops of wheat, fifty-three of oats and nine of barley in the Midlands, Wales and the North; and on sixty-five crops of wheat, twenty-nine of oats and forty-three of barley, in the eastern, southern and south-western counties. The mean counts for all regions are given in Table 1.

Although the number of crops included in the survey was relatively small, and no attempt was made in the choice of crops to secure proportional representation of the acreage of the cereals grown in different parts of the country, or of the differing varieties, the figures in Table 1 provide a fairly convincing indication that instead of assuming a mean of one million ears per acre for all cereals, it is now better to assume 1½ million for wheat and oats, and two million for barley.

TABLE 1

Mean Ear Populations for Thin, Average and Heavy Crops, 1954 and 1955

Cereal	1954		1955		1954 and 1955	
	No. of Crops	*Mean per Acre*	*No. of Crops*	*Mean per Acre*	*No. of Crops*	*Mean per Acre*
Wheat						
Thin crops ..	8	1,100,000	3	1,503,000	11	1,205,000
Average crops ..	37	1,540,000	8	1,618,000	45	1,553,000
Heavy crops ..	28	1,740,000	3	2,243,000	31	1,790,000
All crops ..	73	1,580,000 ± 39,000	14	1,727,000 ± 106,000	87	1,595,000 ± 37,000
Oats						
Thin crops ..	4	899,000	12	1,354,000	16	1,242,000
Average crops ..	11	1,663,000	39	1,765,000	50	1,755,000
Heavy crops ..	0	—	16	2,238,000	16	2,238,000
All crops ..	15	1,459,000 ± 143,000	67	1,805,000 ± 63,000	82	1,741,000 ± 57,000
Barley						
Thin crops ..	6	1,299,000	1	976,000	7	1,252,000
Average crops ..	10	1,931,000	7	2,190,000	17	2,038,000
Heavy crops ..	25	2,506,000	3	2,295,000	28	2,484,000
All crops ..	41	2,190,000 ± 121,000	11	2,108,000 ± 178,000	52	2,173,000 ± 76,412

The figures show that the ear populations in the crops considered "average" by the observers in the light of their practical experience, in fact agreed very well with the actual averages for all crops in the several groups. The wheat crops considered "thin" had a mean population of about 1¼ million ears per acre; those considered "heavy" about 1¾ million. In oats the corresponding figures were "thin", 1½ million; "heavy", 2½ million; and in barley: "thin", 1¼ million; "heavy", 2½ million, with a relatively small proportion of "thin" crops.

Since 1956 the National Institute of Agricultural Botany (N.I.A.B., 1956) have taken 1½ million ears per acre for wheat and oats, and two million for barley, in estimations where it is sufficiently accurate to use an assumed average. In cases of doubt, or where greater accuracy is needed in a particular field, a counting method similar to that used in our survey is employed. The number of ears is counted in one yard of a single drill in each of at least ten quadrats, and the ear population per acre (P) is estimated from the formula:

$$P = \frac{M \times 174240}{W}$$

Here (M) is the mean of the counts per yard of drill and (W) the width between drills in inches. Where (W) is 7 in., as was the case in all but a few fields in our survey, the formula reduces to $P = 25{,}000\ M$, approximately.

The revised limits for the B.M.S. categories for loose smut infection (Moore, 1943) with assumed averages of 1½ million ears per acre for wheat and oats, and two million for barley, become:

Category	*Limits*	
per cent	*Wheat and Oats*	*Barley*
<0·01	Less than 1 head in 33 sq. yards	Less than 1 head in 25 sq. yards
<1·0	Less than 3 heads per sq. yard	Less than 4 heads per sq. yard

It was recommended in 1943 that counts should be made where the infection category exceeds 1 per cent. From the experience of our survey it would appear that counts of infected and total ears in ten one-yard random lengths of drill are adequate for this purpose.

EFFECT OF NUMBER OF SAMPLES ON STANDARD ERRORS

To provide some guidance for future and more detailed surveys, the opportunity was taken of using the counts for each individual yard length of drill at ten sampling sites in each of seventy-three fields of wheat in 1954 to obtain an indication of the effect of number of fields, and number of samples within each field, on the accuracy of the ear-population estimates.*

On the left-hand side of Table 2 the mean population figures are given for the several varieties of wheat included in the group of seventy-three crops, together with the standard errors of the means. These figures are for the counts as actually made (on ten one-yard samples in each field). The number of crops of most of the varieties was insufficient for the counts to reveal significant varietal differences in mean ear population, but the figures serve well to illustrate the effect of number of fields on the standard errors, which are in fact inversely proportional to the square root of the number of fields for each variety.

On the right-hand side of the Table computed values are given for the standard errors that would have been obtained if the number of one-yard samples had been increased to twenty per field, or decreased to five per field, in the latter case with or without doubling of the number of fields. The figures show that in a survey of this kind, where the object is not to obtain very accurate estimates of the number of ears in any particular field, but to ascertain mean populations for a whole region or country, there would be little advantage in doubling the number of samples per field. Halving the number of samples per field (assuming proper randomization), and doing this reduced amount of sampling on twice

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* The analysis was made by E. C. Large of the Plant Pathology Laboratory, Harpenden, with guidance from M. H. Westmacott, then of the Statistics Department at Rothamsted Experimental Station.

In most of the fields the drill width was 7 in. Where it differed from this an initial correction was made so that each individual yard-row sample gave the number of ears per 7/36 sq. yard, or approximately 1/25,000 acre.

The total SS of the counts for all the 730 individual samples was then calculated, together with the variety SS, the field SS and, by difference, the within-field SS, giving an analysis of variance as follows:

	Degrees of Freedom	SS	Mean Square	
Total	729	233,593		
Varieties	6	23,662	3,944	
Between fields	66	104,994	1,591	$(10\sigma_2^2 + \sigma_1^2)$
Within fields	657	104,937	159	(σ_1^2)

Each individual sample count was subject to a standard error of $\sqrt{159}$ or $\pm 12{\cdot}6$ ears per yard of drill.

With (N) = No. of fields per variety, the standard error of each variety mean was:

$$\pm \sqrt{\frac{1591}{10N}} \times 25{,}000 \text{ ears per acre}$$

To estimate the standard error of each variety had (n) instead of ten samples been taken per field, the values for σ_1^2 (= 159), the within-field variance, and σ_2^2 (= 143) the component of variance due to differences between fields, were read or calculated from the analysis of variance. Thus with N fields per variety and n samples per field, the standard error of each variety mean would be:

$$\pm \sqrt{\frac{n\sigma_2^2 + \sigma_1^2}{nN}} \times 25{,}000 \text{ ears per acre}$$

TABLE 2

Mean Ear Populations for Various Numbers of Crops of Different Wheat Varieties Included in the 1954 Survey, with Estimates of the Standard Errors of the Means for such Numbers of Crops, Using Different Sampling Procedures

Variety	No. of Crops	Results of Actual Survey (10 Samples per Field)		Estimated Standard Errors with:		
				Same No. of Fields		*Twice as Many Fields,*
		Mean No. of Ears per acre	*S.E.* ±	20 *Samples per Field* ±	5 *Samples per Field* ±	5 *Samples per Field* ±
Atle	18	1,740,000	74,000	72,500	78,000	55,000
Miscellaneous ..	18	1,530,000	74,000	72,500	78,000	55,000
Eclipse	12	1,530,000	91,000	88,300	97,000	69,000
Cappelle Desprez ..	9	1,680,000	105,000	102,000	110,000	78,000
Hybrid 46	7	1,500,000	119,000	116,000	123,000	87,000
Bersee	5	1,310,000	141,000	137,000	145,000	103,000
Pilot	4	1,260,000	158,000	153,000	165,000	117,000
All crops	73	1,580,000	39,000	38,000	40,000	28,000

as many fields, would, however, considerably improve the accuracy of the estimations, and give a better return for a given expense of sampling time.

SUMMARY

Ear counts made in eighty-seven crops of wheat, eighty-two of oats and fifty-two of barley in various parts of England and Wales in 1954 and 1955 showed a general average population of 1½ million ears per acre in wheat and oats and two million per acre in barley, indicating that the long-assumed general average of one million ears per acre for all three cereals is now too low. Data were obtained on the variation to be expected in thin and heavy crops, and on the effect of number of fields, and numbers of samples within fields, on the standard errors of mean ear population estimates.

The Conference of Plant Pathologists takes this opportunity of thanking all those who participated in this work.

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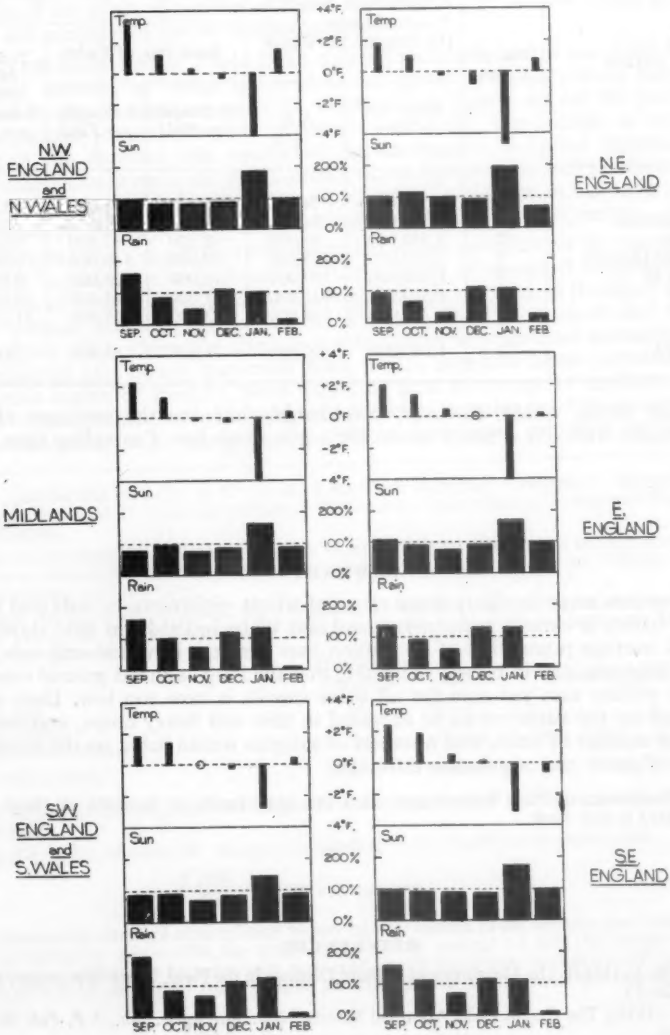
SEPTEMBER - FEBRUARY WEATHER 1958-59

Variations from Average



THE WEATHER OF ENGLAND AND WALES*

AUTUMN AND WINTER 1958–59

THE very wet weather of the 1958 summer continued into September, and was accompanied by warm conditions generally, especially at night. There were severe thunderstorms and hailstorms on the 6th in south-east England, and again on the 14th. The first spell of dry weather for many months occurred about the middle of October, and the second half of November was also dry, although fogs were frequent.

December brought typical early winter conditions, being mainly dull and wet with foggy periods. The coldest month of the winter was January which was also unusually sunny. Snow was fairly frequent in Scotland but lowland England had very little. Fogs were persistent and widespread towards the end of the month. The end of the winter came in mid February, which was an exceptionally dry month; the winds became south or south-easterly and brought temperatures well above average for the last fortnight.

The weather for each of the six months, September to February, inclusive, is represented graphically on page 112. Figures for the six districts of England and Wales are shown in terms of the deviation from the average of air temperature, sunshine and rainfall. The coldness of January is clearly shown; this cold persisted into February and therein counteracted the warmer weather of the latter part of this month, so that the monthly figures are recorded as average. Other self-evident features are the sunshine in January and the absence of rain in November and February.

NEW OR UNCOMMON PLANT DISEASES

Perithecial Stage of Apple Canker on Current Season Shoots. During the wet summer and autumn of 1958 attacks of *Nectria galligena* Bres. were very prevalent in Ireland on current season's growth, and especially so on Laxton's Superb. In January, 1959, the Department of Plant Pathology at the University College Farm, Glasnevin, Dublin, received numerous badly cankered shoots of this cultivar. The shoots varied from 6 to 12 inches in length; the cork was completely dead, the bark scaly, ragged and fissured. On these shoots there was a profuse development of perithecia of the fungus. These fructifications occurred not only in clusters in the cracks and crevices of the bark, but were also studded along the entire shoot (Plate III, 1). After wet autumns, current season's apple shoots which have been killed by *Nectria galligena* have been familiar to members of our Department for over forty years, but this was the first occasion that many perithecia of the fungus had ever been seen on such shoots, although they are quite common on older cankers.

J. B. LOUGHNANE AND R. MCKAY

* These notes and the diagrams on page 112, are provided by the Agricultural Branch of the Meteorological Office, and are published by permission of the Director-General.

A SEPARATING TRAY FOR USE IN THE IDENTIFICATION OF SMALL INSECTS

by A. G. FISKEN*

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DURING a survey of the infestation by aphids of potato and brassica crops in eastern Scotland, water and suction traps were used to obtain information on seasonal fluctuations in numbers of alate aphids. Depending on situation, the traps were cleared at intervals of one to three days and, after processing, the samples were stored until the winter months in 2 × ½ in. sample tubes containing chloral-phenol. As the samples sometimes contained as many as 600 aphids, all of which had to be counted and the potato aphids separated from other species, some quick method of sorting the samples was needed. The details are given here of a separating tray that efficiently met this need.

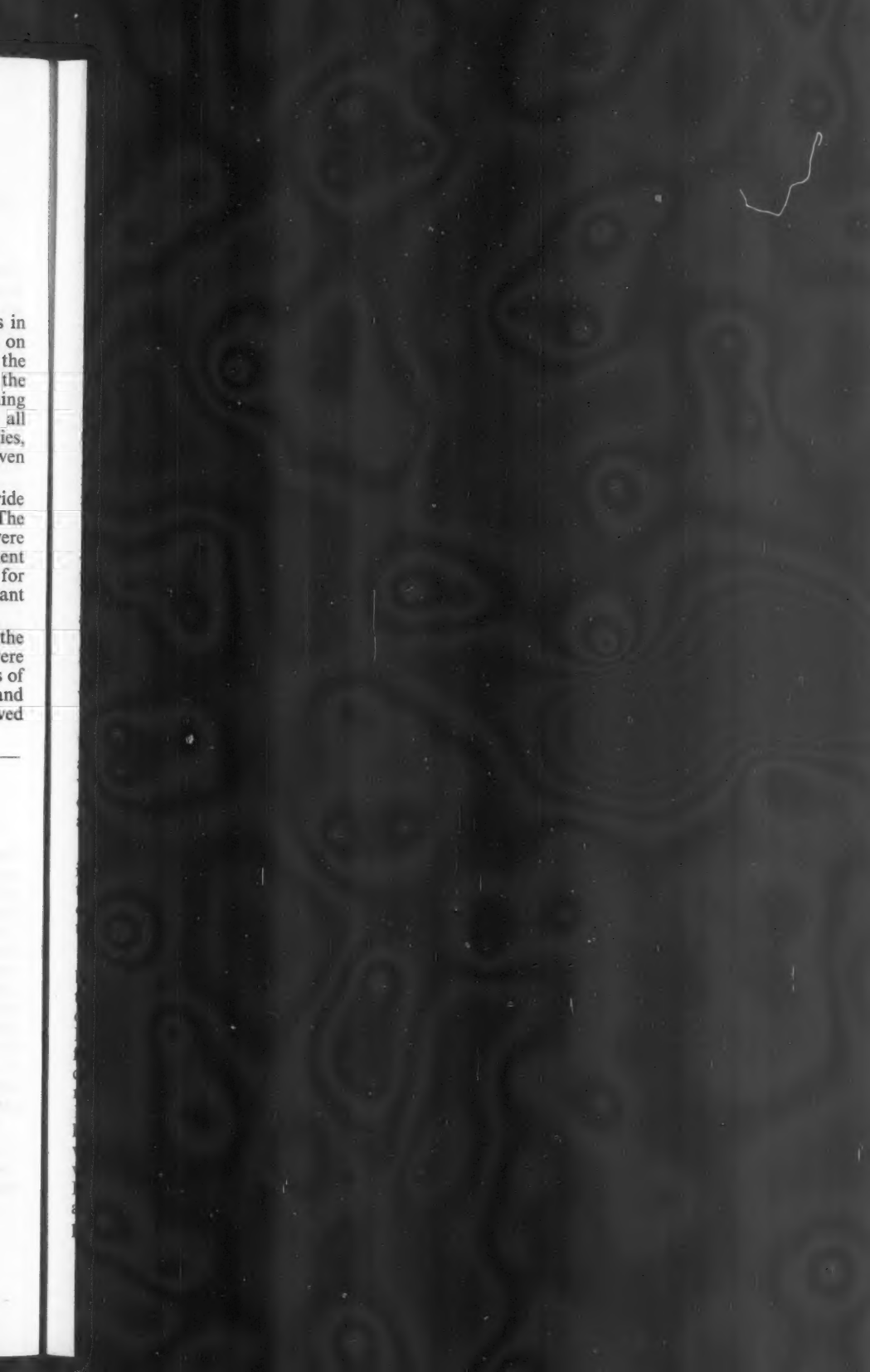
The tray (Plate III, 2) was made from two sheets of white polyvinyl chloride (P.V.C.), of dimensions 4 × 2 × ¼ in. and 4 × 2 × ⅛ in. respectively. The compartments were machined out of the thicker sheet: the large ones were 1 5/16 in. diameter, the connecting channel 5/16 in. wide, and the small compartment ¾ in. diameter. The two sheets were then cemented together with adhesive for acrylic sheet, the thinner one forming the base. These materials proved resistant to lactic acid alcohol and chloral-phenol.

In use, the tray was placed on the stage of a binocular microscope with the connecting channel under the objective. The contents of each sample tube were emptied into one of the large compartments and the aphids moved, by means of a fine paint brush, through the connecting channel, where they were identified and counted. Potato aphids were retained in the central cell and other species moved into the other large compartment.

* Now at Shell Chemical Co. Ltd., Marlborough House, London, W.1.

CORRECTIONS

Vol. 6 (Part 2), June 1959

p. 43, Table 4, last line, *Test Method* 1, *for* "0" *read* "73".
p. 61, line 18, *for* "seedborne" *read* "soil—borne".

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